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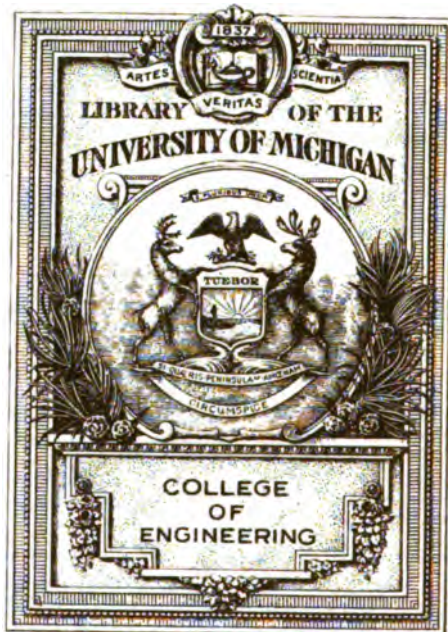
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1921,

THE POWER SITUATION DURING THE WAR

BY

COL. CHARLES KELLER
Corps of Engineers

WITH

APPENDIXES CONTAINING REPORTS ON
CONDITIONS IN THE SEVERAL
POWER DISTRICTS

PUBLISHED BY AUTHORITY OF
THE SECRETARY OF WAR



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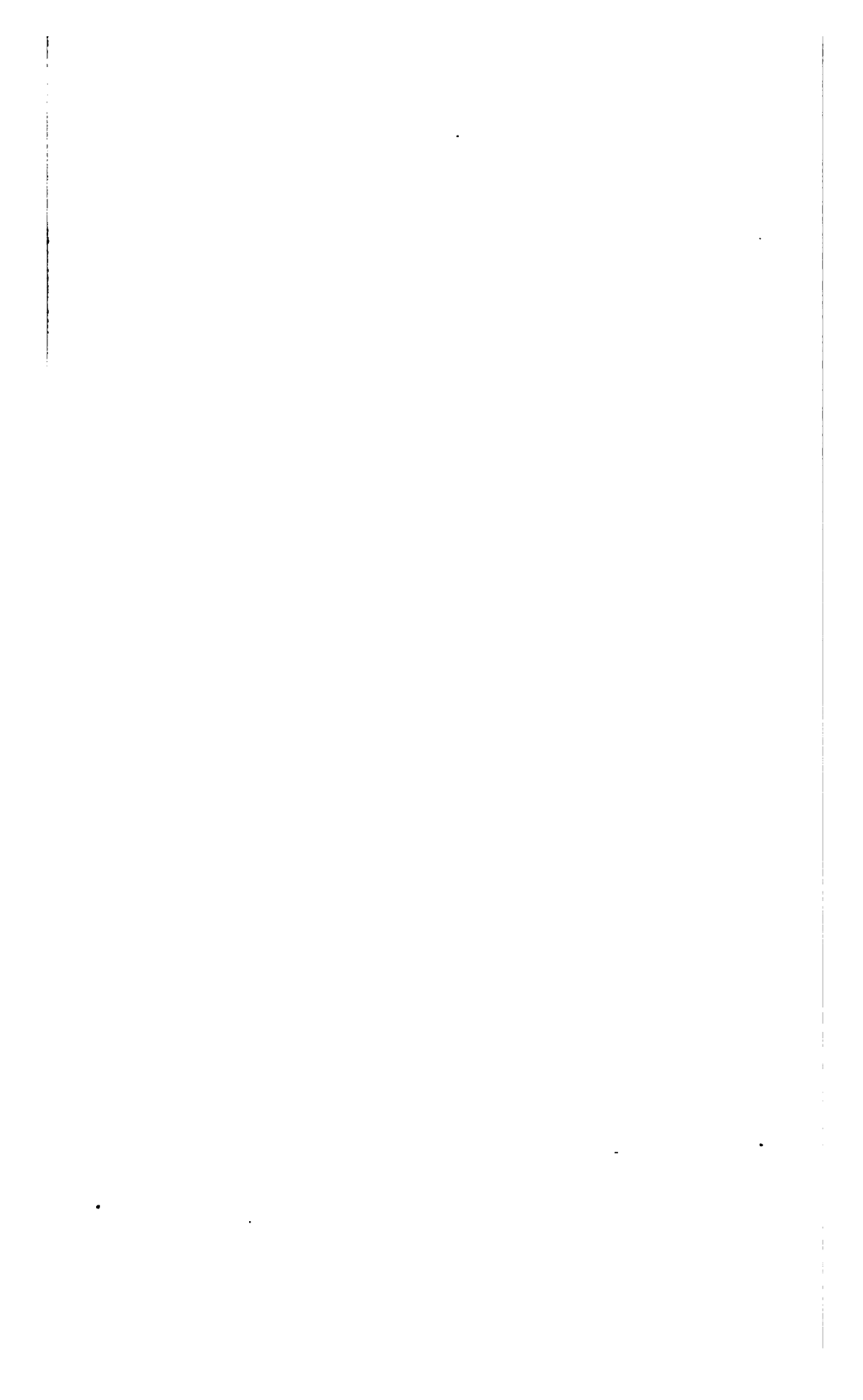
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THE POWER SITUATION DURING THE WAR.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, December 13, 1919.

The honorable the SECRETARY OF WAR
(Through the Chief of Engineers, United States Army),
Washington, D. C.

SIR: Among the many difficulties encountered during the war, having an important bearing upon the war program of the Government, was that created by the exhaustion, soon after our entry into the war, of the reserves of central-station electric power in our principal manufacturing communities. This very naturally at once led to inability on the part of the public-utility companies to honor demands for additional power made by customers with contracts for war supplies of various character, and, as a consequence, threatened to interfere seriously with the production of the equipment and munitions needed for our forces on land and sea.

The Council of National Defense and the War Industries Board, which succeeded to most of the former's functions relating to the control and coordination of our national resources and activities for the benefit of our war program, had early taken cognizance of many fundamental matters such as railroad transportation, coal production, supply of basic materials such as copper, lead, zinc, and of many others of obvious importance, and had established the instrumentalities for dealing with them. But neither of these agencies took any steps for the ascertainment of our exact resources in electrical power and for the adoption of a policy to govern the assignment of existing supplies and the procurement of necessary increases. This statement of fact is not meant to imply any lack of proper care and watchfulness on the part of the established public agencies of control.

The first evidence of impending power shortage that came to the Government was rather indirect in character. It consisted in complaints to the Secretary of War from manufacturing interests at Niagara Falls and Buffalo, N. Y., to the effect that the Canadian authorities had already seriously curtailed the exportation of hydro-electric energy from Niagara Falls, Ontario, into the United States, and that a movement was on foot in Ontario to induce the Canadian authorities to prohibit altogether the export of electrical energy to the United States.

In the western part of New York State since about 1890, concurrently with and caused by the increased development of power derived from Niagara Falls, there had grown up a large and important center of the electrochemical, electrolytic, and electric-furnace industries, whose best-known products are chlorine, bleaching powder.

phosphorus, abrasives, calcium carbide, ferrosilicon, and other ferro-alloys, electrodes, and aluminum.

These industries were grouped in and near Niagara Falls, N. Y., with a number of important establishments at Buffalo, some of which were peculiarly dependent on power imported from Canada, while all those mentioned and many others in the district were of vital consequence to the success of our war endeavor. Thus, chlorine was of first importance in the manufacture of the various kinds of poison gas; phosphorus is used in the preparation of smoke screens and smoke bombs; the artificial abrasives are indispensable in all the grinding and sharpening processes so necessary in machine shop practice; calcium carbide is now absolutely demanded for use in miners' safety lamps, so that the maintenance of our coal output depends upon keeping up the supply of carbide; ferrosilicon is needed to insure the soundness of steel, particularly of the high-grade steel used in gun and shell forgings and in the vital parts of machinery; silicon itself is used in the manufacture of balloon gas; electrodes are essential to the rapidly growing electric furnace industry of the country, and the varied uses of aluminum, particularly in aeroplanes, are well known.

The Niagara Falls-Buffalo district, in some cases, makes all, in others, a large part of the output of the entire country in the products above mentioned, and any danger of interruption or diminution of their manufacture was too grave to be ignored. Accordingly, the Secretary of War designated the Hon. R. J. Bulkley, then chairman of the legal committee of the War Industries Board, to make an investigation of the complaints and to confer with the Canadian authorities concerned with a view to such adjustment as would be most favorable to our common interest in the successful prosecution of the war.

Before departing from Washington, Mr. Bulkley called upon the writer in the office of the Chief of Engineers for the purpose of familiarizing himself with the history of power development at Niagara and of securing additional information from the files of the Engineer Department which, since 1906, had been directly charged with all responsibility for the enforcement of the various mandates of Congress respecting the development of power on the New York side of the border at Niagara Falls. Incidentally, the writer had himself, practically from the passage of the Burton Act, been identified more or less continuously with the control, regulation, and investigation of matters connected with the development of water power at Niagara Falls and was thoroughly acquainted with the local conditions, and was thus in a position to be of service to the representative of the Secretary of War, as well as to the best interests of the United States. This circumstance is mentioned, however, only because of its ultimate influence in leading to the formation of a governmental agency for dealing with the general power problem of the war, this agency being the power section of the War Industries Board.

The power situation in the Niagara Falls-Buffalo district in the fall of 1917 was as follows: At Niagara Falls, N. Y., there were two hydroelectric power companies, the Hydraulic Power Co., and the Niagara Falls Power Co., both producing power from water diverted from the Niagara River above, and returned to the river below the Falls. These companies were in existence at the time of the passage of the Burton Act, in June, 1906. Until its expiration

they operated under War Department permits, the Hydraulic Power Co. being authorized to divert 6,500 cubic feet per second, and the Niagara Falls Power Co. 8,600 cubic feet per second. After the expiration of the Burton Act, in 1913, these two companies operated without permits, but under the same limitations and rules as had previously been in force. The Hydraulic Power Co. delivered water, electrical, and mechanical power, practically only within the limits of Niagara Falls, N. Y., the amount of water power delivered as such being relatively small, while a very considerable portion of its output was delivered as mechanical power upon the shafts of generators belonging to the Aluminum Co. of America, installed in the newer or No. 3 power house of the Hydraulic Power Co. This company had two power houses, No. 2 and No. 3. The Niagara Falls Power Co., also with two power houses, normally delivered the energy derived from about 7,900 cubic feet per second as electricity not only in Niagara Falls, N. Y., but at Buffalo and in the intervening towns. Its remaining authorized diversion, about 700 second-feet, under an agreement with the International Paper Co., was diverted from the intake canal of the power company, into a canal and power house of the paper company, and converted into mechanical power for grinding wood pulp. The Niagara Falls Power Co. ordinarily supplemented its supply of power by the importation from Canada of power generated by its subsidiary, the Canadian Niagara Power Co., this power being transmitted from Canada over two lines, one to Buffalo, and the other to Niagara Falls, N. Y. Up to 1916, these were the only important companies in this territory engaged in the production of electrical energy. In addition, there was, however, the Niagara, Lockport & Ontario Power Co., which was engaged in the distribution of Niagara Falls power received from Canada over the lines of the Ontario Power Co., originally built and controlled by the American interests identified with the Niagara, Lockport & Ontario Power Co. The latter company owns a high-tension transmission line extending from Niagara to Syracuse, N. Y., and normally its business is the delivery of Niagara power, supplemented by steam and by other smaller supplies of water power, derived from the Oswego and Salmon Rivers, to industries, public utilities, and distributing companies, between Niagara Falls and Syracuse.

The tremendous industrial activity resulting from the war orders placed by the English, French, and Russian Governments, in the Buffalo-Niagara Falls territory had, in 1915, resulted in so complete an exhaustion of surplus power that the Buffalo General Electric Co., which up to that time had been engaged only in the distribution of Niagara Falls power received over the transmission lines of the Niagara Falls Power Co. and the Canadian Niagara Power Co., finding itself unable to secure further hydraulic power from Niagara Falls, began the construction at Buffalo of a steam power station with an initial installation of three 15,000-kilowatt turbogenerators. These generators had been completed and were in operation early in 1918, and to meet the constantly swelling demand the company had, before our entry into the war, also ordered machinery and begun construction for the installation of a fourth unit of some 35,000 kilowatts capacity.

From the preceding it will be seen that power generated at Niagara Falls, Ontario, and exported over lines belonging to the Niagara Falls Power Co. (or its Canadian subsidiary, the Canadian Niagara Power Co.) and to the Niagara, Lockport & Ontario Power Co. formed part of the supply of the highly important industrial area of western New York. There are three companies at Niagara Falls, Ontario, engaged in the production of electrical energy from water diverted from the Niagara River above, and returned to it below the Falls, and two of them had been financed and constructed by American interests under plans that contemplated the exportation to the United States of at least half their output. Indeed, for the purpose of protecting Niagara Falls from damage due to the too great diversion of water it had been deemed expedient to insert in the Burton Act in 1906 not only a limitation (15,600 cubic feet per second) upon the quantity of water that might be diverted from the Niagara River within American territory, but also one upon the quantity of energy (160,000 horsepower) that might be received from Niagara Falls, Ontario, and each of the three Canadian companies or their allied interests at that time presented arguments and fought vigorously for the privilege of exporting the greatest possible portion of the allowable total of 160,000 horsepower. Permits were actually issued by the War Department in 1906 for the importation into the United States of Niagara Falls power as follows: To the Niagara, Lockport & Ontario Power Co. for 60,000 horsepower; to the Niagara Falls Power Co. for 52,500 horsepower; and to interests identified with what is now called the Toronto Power Co. (formerly Electrical Development Co.) for about 45,000 horsepower. At that time eastern Ontario had been but little developed industrially, the power market in western New York was practically the only one, and it was natural that the Canadian power companies should seek to enter and supply it.

The condition last described continued practically until 1915, and while in the meantime the Hydroelectric Commission of Ontario had been created and had begun the distribution of Niagara Falls power throughout the portion of Ontario between the Niagara and the Detroit and St. Clair Rivers it was only after the intense industrial activity resulting from Canada's participation in the war in Europe had exhausted the formerly large surplus of hydraulic power in this part of Canada that the demand was made that export to the United States be prohibited. The maximum exportation to the United States never had exceeded 112,500 horsepower, the total authorized in the permits issued to the Niagara Falls Power Co. and the Niagara, Lockport & Ontario Power Co. and the practical limit of capacity of their transmission lines, no line having ever been installed under the third permit. But this total of 112,500 horsepower had gradually been reduced to about 90,000 horsepower, a reduction of some 20,000 horsepower. While this loss was less than 5 per cent of the total amount of energy available on and near our Niagara frontier, the great demand for power by our own war industries and the already existing inability to supply demonstrated needs of old and important customers caused this reduction to be seriously felt and added to the apprehension raised by the threat to prohibit completely any export of power from Canada.

This was the state of affairs found by Mr. Bulkley to exist at the time of his first, and necessarily general, investigation at Buffalo, Niagara Falls, and near by, and realizing the gravity of the situation he arranged, at a conference with Sir Henry Drayton, who, as power controller, was the Canadian official in authority, for the maintenance of the amount of power exported from Canada, unchanged as it then stood, until a careful investigation had been made into the employment of Niagara power on both sides of the border and a general policy formulated for the use of this power only in essential war service.

It was agreed that the interests of both nations called for the greatest possible production of needed war materials of the kind peculiarly dependent upon a cheap and dependable supply of electricity and that all decisions subsequently made should recognize this community of interest. It is a pleasure to say here that throughout these negotiations and the relations that were brought about by the recurrent difficulties with respect to Niagara Falls power, particularly during the severe winter of 1917-18, when heavy ice obstructions for a time reduced the output of the two American companies to a very small percentage of the normal, the attitude of Sir Henry Drayton as power controller was not only fair but generous, and that he consistently held in view as the foremost consideration in the allotment of power the importance of fostering and stimulating the production of war essentials regardless of whether they were being made in Canada or in the United States.

Following this preliminary agreement Mr. Bulkley returned to Washington, and with a view to making the field investigations necessary to determine the nature of the uses of Niagara power he requested and secured the consent of the Chief of Engineers to my assignment to cooperate with him and to the employment of the field forces of the United States Lake Survey for making the required field examinations. These field investigations took until after the middle of November, as the territory was relatively large while their scope expanded so as to include consideration also of the steam-electric resources of the region and the possibility of supplementing the water power therefrom. Finally it was deemed desirable to call into public conference the principal power-using interests of the region and to present for their discussion an outline of the policy which it was proposed to apply in respect to the assignment of power. This meeting took place toward the close of November, 1917. The free discussion that then took place developed definitely the needs and hopes of the large industries of the district, but no good argument was presented against the enforcement of the proposed measures, which included the elimination of the use of power for nonessential purposes, and of its use for essentials beyond the extent judged necessary for the safe maintenance of our war output; the reduction of supply of Niagara hydraulic power to public utilities and distributing companies having steam stations and compelling these companies to operate the steam stations even when these were uneconomical; the granting of permission to both power companies at Niagara Falls to divert all the water that they could usefully employ to generate power; the employment of all means available to the United States to expedite completion of the large new steam units of

the Buffalo General Electric Co., and of the Niagara, Lockport & Ontario Power Co.'s steam plant at Lyons, N. Y.; the actual feeding of surplus steam power from Rochester and Syracuse to the system; the maintenance of the Canadian supply unimpaired by means of an arrangement under which a considerable additional supply of coal was procured for Canada; and, finally, the allotment of all the power thus rendered available to those industries, necessarily users of electrical energy upon a large scale, indicated by competent authority as being most in need of it.

The final results are shown in Table B, page 67 of Appendix A herewith, which indicates that by the above curtailments, economies, and additions, 19,587 horsepower was assigned to stimulate the production of ferrosilicon, 6,284 horsepower for electrodes, 2,217 horsepower for abrasives, 3,000 horsepower for phosphorus, 4,000 horsepower for sodium cyanide, and 2,501 horsepower for chlorine; the total increase being 37,589 horsepower. In practically every case the increase in power assigned was equal to the idle manufacturing installation of the industry in question. For further details of the manner in which this power was secured, reference is invited to the report hereto attached, Appendix A.

On the day following the conference with the industrial interests, a meeting was had with Sir Henry Drayton, at which the power situation on both sides of the boundary was carefully considered in the light of the specific information made available by the inquiries conducted since October. The policy above described, varied in such features as were not applicable to Canadian circumstances, and with the addition of a provision for economy in the lighting of shops, theaters, etc., was accepted as on the whole, promising the greatest possible advantage to the allied cause, and it was agreed that it should be put in effect.

To do so it was necessary that the Government keep in constant touch with and control of the situation, and this in turn required that an agent of the Government, armed with adequate authority, be kept on the ground in or near Buffalo. A similar need having developed at Pittsburgh, the Secretary of War decided to appoint Mr. Bulkley and the writer as power administrators to represent him and to discharge the legal authority of the War Department in respect to the assignment and distribution of electric power wherever shortage difficulties might exist. This authority was exercised and discharged in the manner that will hereafter be described.

While the various power-generating companies in the Niagara Falls-Buffalo region were in cordial and helpful accord with the plan for economizing power and redistributing it so as to enhance the output of essential war products, their contract obligations as to Niagara power suggested the danger that curtailment of the contract supply to nonessential consumers might lead to suits for damages against the power companies unless the orders of the Government with regard to the matter were so drawn as to relieve the power companies of all legal liability for breach of contract. It was plainly equitable that the power companies should be protected against loss due to their obedience to the orders of the representatives of the United States, and accordingly Mr. Bulkley and his associates of the legal committee of the War Industries Board prepared carefully

drawn instruments under which the entire output of power of the Hydraulic and Niagara Falls Power Cos. was requisitioned by the President of the United States, and direct control of the companies was thereafter waived by the Secretary of War on condition that these companies, in the ordinary conduct of their business, deliver power to the beneficiaries specified in the schedule accompanying the instrument of waiver. This method proved both successful and satisfactory. Under it the authority of Maj. Hardy, who was placed on duty at Buffalo and entrusted with the task of supervising the power situation in this district, proved entirely ample, while at the same time the continuance of operation by the trained forces of the two companies permitted a degree of flexibility in the operating program attainable only with a personnel thoroughly familiar with the needs and peculiarities of the industries concerned. Constant watchfulness and unvarying desire to serve the public interest were necessary in order that the power available might be put to its highest use, and both companies at all times afforded to the representatives of the United States just this kind of cooperation.

The ever-shifting situation presented constantly varying problems. Thus, the placing of all available steam plants in operation involved an enhanced use of coal at a time when coal was in great demand everywhere. At no time during the winter of 1917-18 did the great steam plants of the district, such as those at Buffalo, Lyons, and Syracuse, have more than a few days' stock on hand, and on several occasions one or more of them were down to a day's supply or less, so that it was never certain that these important power houses could be kept in operation. This rendered it necessary to intervene constantly with the Fuel Administration at Washington, and to secure special concessions for these companies. Added to this difficulty were the ice conditions of the Niagara River during the latter part of January and nearly all of February, 1918, as a result of which the output of virtually all the power companies on both sides of the border was very materially reduced. At one time one of these companies was able to deliver only about 20 per cent of its normal output. Practically constant intervention and supervision were required on the part of the agents of the United States.

It was also necessary to make equitable apportionment of the cost of the sometimes uneconomical steam power brought into use. As a rule, this was not transmitted to a distance, but was used near the point of generation to replace Niagara hydropower employed during normal times, permitting the hydro power thereby released to be retained for use at or near Niagara Falls. But the steam power frequently cost as much as a cent or more per kilowatt hour, or, say, \$60 or more per annual horsepower, while the water power was ordinarily sold for \$12 per horsepower up, depending on the amount involved, the age of the contract, and the distance of the point of delivery. Thus, the Buffalo General Electric Co. released to the Niagara Falls Power Co. a large block of hydraulic power, 10,000 horsepower, and supplied its customers with steam power. Obviously, any expense due to this transaction should properly devolve upon the industries to which this 10,000 horsepower of hydraulic power was assigned, and this was the course actually pursued. Other cases were somewhat less simple, and some of the steam power

was much more expensive, but in the face of the necessity of prosecuting with the utmost vigor and ending at the earliest possible moment a war that was costing the United States above \$30,000,000 per day, ordinary considerations as to cost of product had to be neglected and quantity regarded as the only goal.

The measures adopted in the Niagara Falls-Buffalo district, as above described, were recognized as mere palliatives, and it was seen that, for any prolonged war, it would be necessary to relieve as much as possible the strain upon our coal supply by the further development of water power at Niagara. Fortunately, as a result of the joint resolution of June 30, 1917, an investigation was already under way which had for its object the determination of the most efficient comprehensive policy for the development of water power from the Niagara River, and it was possible to employ the technical force engaged in this investigation under the orders of Col. J. G. Warren, Corps of Engineers, upon the task of preparing such plans as would most quickly result in a sensible addition, say not less than 50,000 horsepower, to the amount of water power available, while at the same time interfering little, if at all, with the most desirable comprehensive plan for power development at Niagara Falls. Such a plan was presented by Col. Warren March 2, 1918, was approved by the Chief of Engineers, and thereafter authorized to be placed in effect by the Secretary of War. Under this plan it was proposed to deepen the intake canal and enlarge the headworks of the Hydraulic Power Co. and to extend its power house No. 3 so as to permit the most efficient possible use of the 4,400 cubic feet per second not previously permanently allotted to either of the two power companies. While 3,650 cubic feet per second of the unused part of our authorized diversion had already been temporarily assigned to these two companies, neither was able to use this water efficiently, and it was figured that, under the plan selected by Col. Warren from among quite a large number, the cessation of inefficient use as soon as the new installation became available and the substitution of works and machinery in which the fullest possible advantage would be derived from the energy of the diverted water would result in a net gain of at least the minimum of 50,000 horsepower above mentioned. This plan was deemed the most favorable of those presented, because the work necessary for its completion was simpler and attended by fewer uncertainties. Furthermore, the Hydraulic Power Co. had ample resources of all kinds necessary to insure the earliest possible completion of the work and placing in use of the resultant power. It was estimated that all construction would be complete and the new power available in the spring of 1919. In addition, it was planned to create new works for taking advantage of the firm diversion of 8,600 second-feet assigned to the Niagara Falls Power Co., so as to produce therefrom about 172,000 horsepower, thereby making a further net gain of about 80,000 horsepower, which would not however have been ready for use until some time in 1920. For an explanation in greater detail of the reasons for selecting the preferred plan and of the features of this plan reference is invited to Appendix A, which is derived from a report prepared by Maj. C. S. Lacombe, United States Engineers.

The net result of Government control of power in the Niagara Falls-Buffalo district was, first, the release of about 37,600 horsepower to war industries, an increase of over 25 per cent in the amount of power before used by the same industries; second, an intelligent control, in the interest of the war program, of the distribution of power in the intensely active manufacturing area between Syracuse and Niagara Falls-Buffalo; third, constant help and support to all the power companies of this area with a view to the uninterrupted delivery of their maximum output; fourth, harmonious and efficient cooperation between all these power interests; and finally, a friendly and mutually helpful understanding with our Canadian allies.

The reason for describing at such length the situation at and near Niagara, and the remedies adopted, is that here were developed the various steps necessary to be taken in the handling of similar difficulties elsewhere. These steps in correct order are, first, the making of a careful survey of the territory, including related areas, for the purpose of ascertaining in precise detail the power resources of the district, the size and condition of the generating units and boilers, the capacity of transmission systems, reserves available, plans made for expansion and enlargement, including orders entered for equipment necessary thereto, amount and character of existing load and of prospective or unfilled demand, and possibility of securing necessary relief from neighboring systems; second, the preparation, or the securing from the appropriate public agency, of a preference or priority policy to be placed in effect in times of stringency until measures for enlarging the power supply shall have become effective; under this priority policy the producers of nonessential or less essential articles would be deprived of power to the extent made necessary by shortage of power for the production of articles deemed indispensable to the proper conduct of our war operations, while, if necessary, saving in power would also be secured by cutting down unnecessary street and display illumination, and, as a last resort, peaks reduced by the enforcement of a proper time schedule assigning varied opening and closing hours to the diverse industries; third, plans should be prepared for increasing the power supply so as best to meet the needs developed by the survey, such plans contemplating first the installation of the additional capacity required to meet the immediate needs of the emergency, and next the installation of such further capacity as may be judged necessary to meet the more slowly expanding requirements of a modern war of several years' duration. These plans should contemplate the utilization of both steam and hydraulic sources of supply, of which the latter will usually be included among the elements designed to answer deferred requirements permitting the adoption of measures calling for considerable time in their execution. Interconnection of adjoining systems by comparatively long transmission lines will be included in both the short and the long time provisions, with a view to taking advantage of unused capacity, diminishing the total reserve held idle, and utilizing power released by the diversity often existing in the incidence of demand in even adjoining districts. The value of such interconnection was clearly shown in the Niagara Falls-Buffalo experience, although the interconnection here was far from being complete, and some of it was indirect.

The fourth step in handling power shortage difficulties should be prompt canvass of our situation as to boilers, generators, motors, transformers, water wheels, and other appliances necessary in producing either steam or hydraulic power and of our manufacturing resources along these lines with a view to formulating a comprehensive policy for distributing these appliances so as best to meet the national needs. The direct needs of the Army and Navy should, of course, be given due weight and precedence in any such schedule of distribution, but no governmental agency other than the Power Administration should have authority to requisition either power or power-producing machinery. Such needs should be filled by the Power Administration, which alone would be qualified to estimate correctly the relative importance of the numerous demands, performing in respect to them a general coordinating function.

The fifth step, not in order of time, however, in handling the power problem should be the prompt creation of an adequate organization for making the necessary power surveys, for the preparation of plans for expanding our power supplies, for canvassing the situation as to machinery and boilers and making schedules for their allotment, and finally for supervising the distribution of power supplies. This organization should be headed by a power administrator, preferably an engineer of wide experience in the management of important public-utility enterprises and therefore familiar with the practical problems sure to arise. He should have a numerous staff of electrical engineers similarly qualified, as well as a sufficient number of hydraulic and mechanical engineers to permit the prompt handling of all questions arising in these lines of activity, and the necessary clerical staff as well. The power administrator himself might, however, also well be an Engineer officer, specially qualified for the duties by study, training, and experience. His technical assistants should also be commissioned as Army officers in appropriate grades, as much for the sake of keeping them permanently under control, as because during the war it was found that the uniform carried with it a high degree of respect, consideration, and obedience on the part of the community, thereby facilitating the discharge of duties often disagreeable in their consequences to all concerned.

The administration should be decentralized to the greatest practicable extent by dividing the country into regions or districts, each under a local administrator, who should be charged with enforcing within his jurisdiction all orders and policies of the power administrator and of supervising the making of all plans, investigations, and surveys relating to the power situation within his territory and of preparing recommendations and projects for consideration and coordination by the central Power Administration. Each local administrator will, of course, require a small technical and clerical staff. Tentatively, the country might be subdivided into the following districts or regions: The New England States; Greater New York and its immediate surroundings; New Jersey and eastern Pennsylvania; western Pennsylvania and eastern Ohio; northern New York State, including Niagara Falls and Buffalo; Alabama, Georgia, Tennessee, and the Carolinas; Chicago and its immediate surroundings; St. Louis and vicinity; Minneapolis and St. Paul;

and the Pacific Coast States. The districts as thus generally outlined differ greatly in area, but the subdivision has been made consistent with existing and probable future industrial development. It is, moreover, tentative, though largely in accord with experience during the war. In the closing portion of this report is suggested a method of organizing during peace and keeping up to date the skeleton of just such an agency as is herein contemplated, so that on the outbreak of war it will be necessary merely to mobilize and set at work, largely along predetermined lines, the remainder of the needed personnel. The peace-time organization is intended to be used in compiling and keeping currently correct the data regarded as useful and necessary for the conduct of war upon a great scale.

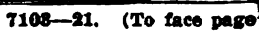
PITTSBURGH DISTRICT.

While the power difficulties at Niagara Falls and Buffalo were under investigation and in course of adjustment as above described, complaints were received by the Secretary of War in regard to conditions at and near Pittsburgh. At this place, the heart of the steel industry of the country and an important center in the production of coal, of heavy machinery, of railroad equipment, of electrical apparatus, and of rubber tires, a congestion of war orders and manufacturing had completely exhausted the power resources of the district, which includes not only Pittsburgh itself, but the contiguous mining territory in southwestern Pennsylvania west of Connellsville and the Youghiogheny River, all of the Panhandle of West Virginia north of Wheeling, and virtually all of the important industrial and mining section of Ohio east of a north and south line passing near Akron, as well as a considerable fraction of Pennsylvania to the north of Pittsburgh and east of the Ohio line. So far had some of the central stations gone in their effort to serve the public that the breaking point was actually reached, causing vital damage to boilers and machinery, so crippling them as to lead to a serious reduction in output. The first complaints received by the Secretary of War were from the city of Pittsburgh to the effect that street railway schedules had been altered so as to diminish the number of cars and car trips, especially during the morning and evening hours, thereby inconveniencing the working and business people and causing public dissatisfaction, which was increased by the fact that an attempt had been made to place power consumers on a rotating or alternating schedule and to require them to remain idle at certain prescribed times. The importance of maintaining satisfactory conditions and of promoting the maximum possible output in Pittsburgh was such as to induce the Secretary of War to interest himself actively, and he therefore assigned Mr. Bulkley to make an investigation. This was early in November, 1917. On visiting Pittsburgh, Mr. Bulkley found conditions to be substantially as reported, the difficulties, in the main, being due to a concentration of Government orders and contracts in the city of Pittsburgh which, in turn, had led to a cumulative growth in power demand and to an eventual overloading of the local public utility company, the Duquesne Light Co., which supplied power not only to the public in general, but also to the street railways of Pittsburgh and to the West Penn Power Co., a public utility having also power plants and transmission lines of its own in the territory extend-

ing around and south of Pittsburgh from east to west. The preliminary investigation showed that some alleviation of the difficulties might be produced by causing these two companies to cooperate more fully and a provisional agreement to this effect at once permitted the restoration of normal car schedules and power service. But the constant growth in demand, due to increasing war orders, as well as to the advance of winter, with its shorter days and darker weather, soon made this temporary adjustment unavailing, and it became necessary to have technical experts look into the situation, with a view to devising more permanent and efficient remedies. The first power survey of the district was accordingly made in December, 1917, and January, 1918.

The principal manufacturing cities of the district are Pittsburgh, Connellsville, Wheeling, East Liverpool, Steubenville, Canton, Massillon, Alliance, Akron, Warren, and Youngstown, and it is also an important coal mining region. Power difficulties existed at practically all these places—some of which were overcome by the reduction of non-essential uses and by a program of preferential treatment but the survey showed the existence of a practically unlimited demand for power, which had been temporarily postponed by the issuance of orders prohibiting the placing of further Government contracts, while it was also demonstrated that all power plants were fully loaded and that some had broken down and needed extensive repair. At the same time, with the exception of the plant under construction at Windsor, 12 miles above Wheeling on the Ohio River, no additions to the power supply of the district were in progress, nor were the public utility companies in position to make such additions from their own resources.

The comprehensive study of the situation showed, first, that the immediate danger at and near Pittsburgh was that the overtaxed plants of the Duquesne and West Penn Cos. would at some time be irretrievably damaged. To obviate this danger a program was prepared for the progressive repair of those units that had already been damaged or that were in any way under suspicion, and this work was promptly inaugurated, every possible support being given to it by the power section which, at this time, was being organized and was beginning to function. Priorities for the necessary labor and materials were secured and such other official assistance given as was thought useful. While some of the defective units were thus repaired, the work was by no means completed at the time of the armistice. The second showing of the survey was that radical improvement of conditions in the Pittsburgh district was vitally necessary in order to utilize fully for war purposes its immense industrial potentialities, and that such radical improvement should be based upon the adoption and early completion of a logical plan for the interconnection of the power plants of the district and the installation of additional machinery principally in new superpower plants located substantially at places previously considered by the various companies involved. Such a plan was accordingly prepared and is shown on diagram herewith. As will be seen, it contemplated the construction of 100,000 kilowatts of additional generating capacity in 1918 and 230,000 kilowatts to be completed in 1919, together with the installation of new transmission lines to connect the principal generating sources. The plan, while admitted by the interests concerned to be



an excellent one, proved to be financially out of the question, because the individual companies had either exhausted their resources or did not feel justified in defraying the war cost of power plants or any part of the cost of transmission lines whose principal or sole purpose was insurance against breakdown.

After many conferences between the representatives of the various power interests and the power section the conclusion was reluctantly reached that local initiative could be depended on little, if at all, and that, if any part of the plan was to be executed, it would be necessary for the United States to afford financial help. Unfortunately no governmental agency was directly interested at any one of these localities to such preponderating extent as to indicate that agency as the only or the principal beneficiary of the resulting facilities. Thus in the Pittsburgh district various branches of the War Department were procuring supplies and war materials; the Navy was purchasing armor, projectiles, structural steel, boilers, and machinery; and the Emergency Fleet Corporation was buying, either direct or through commercial shipyards, plates, shapes, boilers, and all classes of machinery. It was therefore difficult in the absence of direct authority of law under which Government funds were provided for the purpose to see just how financial aid could be given. Similar shortages of power and complexity of interests on the part of governmental agencies existed also in the New Jersey and eastern Pennsylvania district, and during July, 1918, an agreement was finally promoted between the War Department, the Navy Department, and the Emergency Fleet Corporation under which the War Department was to assume the obligation of financing power extensions in the Pittsburgh district, the Navy in New Jersey, and the Emergency Fleet Corporation in Philadelphia, following generally plans formulated by the Power Administration.

Accordingly, in the Pittsburgh district the power section, on behalf of the War Department, invited the various power interests to indicate the terms under which they would be willing to undertake the construction of the power extensions included in the comprehensive plans before mentioned. The only response that did not demand that the Government assume the entire risk and pay the full cost was from the West Penn Power Co., which submitted a proposal that the Government should advance 40 per cent of the cost of a new power plant of 40,000-kilowatt capacity to be built at Springdale on the Allegheny River, about 12 miles northeast of Pittsburgh and not far from Cheswick, which is shown upon the plan for increasing the power supply of the district. The amount advanced by the United States was agreed to be repaid to the extent that the reproduction cost, determined by appraisal three years after the termination of hostilities, might exceed the portion of the original cost paid by the company itself. Work under the contract was promptly begun, and it was anticipated that power would be delivered some time in 1919, which, considering the magnitude of the operations and the difficulties, indicated exceedingly energetic prosecution of operations. The plant is of the so-called superpower type—that is to say, the units are large, 20,000 kilowatts each—and it is situated close to a large supply of condensing water and of good steam coal, for which no rail transportation will be required. Except in so far as individual pref-

erence may dictate the installation of somewhat larger generators, this design represents the extreme limit of efficiency in central station practice, and future development will undoubtedly continue largely along similar lines.

Before leaving this subject it seems proper to make formal acknowledgment of the spirit of cooperation and disinterestedness shown by the officers of the West Penn Power Co. throughout the negotiations with them. Too much can not be said in appreciation of their good will, liberality, and entire straightforwardness.

Subsequent to the conclusion of this contract the Duquesne Light Co. revised its original refusal to underwrite any part of the cost of desired extension of its system and a similar agreement was tentatively made for the installation of additional boilers in its Brunot's Island plant which would have permitted an increase of its output by about 15,000 kilowatts. At the time of the armistice negotiations were also under way looking toward the completion of a similar contract for the construction of a superpower station of 120,000 kilowatts capacity, but the termination of hostilities put an end to the matter.

To sum up, it may be said that the installation of a priority program for power service, the establishment of a schedule for repairing deteriorated generators, the enforcing of more helpful relations between conflicting interests, the furnishing of important assistance in securing coal during times of stringency, and the initiation of work under the comprehensive plan for interconnection and new construction represent the full extent of progress made in remedying power difficulties in this district. In the absence of legislation bearing upon this matter nothing more could be accomplished. While the help given was of vital importance in keeping up the output of this great manufacturing district, it should be noted that the time, the means, and the authority available were all too little to enable trouble to be completely avoided. The real power shortage in 1918 was at least 130,000 kilowatts and even this figure is based upon conditions under which the placing of war orders had been restricted in order to avoid complete congestion. For further details attention is invited to Appendix B.

Incidental mention has been made of the power section, and the orderly presentation of the details of our war-power problem and of the steps taken to solve it requires that at this point the history of the organization of the power section of the War Industries Board and of its operations be given.

As has already been stated, specific power difficulties at Buffalo, Niagara Falls, and Pittsburgh manifested themselves and were brought to your notice in November and December, 1917, and at that time you called upon Mr. R. J. Bulkley and the writer to investigate these troubles and to advise you as to the necessary remedies. Knowledge of the gravity of these cases and general information as to industrial activities elsewhere led to the inference that if similar troubles were not at that time actually general and wide-spread, they soon would be, and it therefore seemed that to protect our war program from embarrassment and delay, and to furnish authoritative information regarding power conditions upon which the allocation of war orders could be based, it was necessary at

once to create an agency endowed with the authority and the qualifications to deal adequately with the matter. This view was informally presented to you, and you approved a general plan to gather together a body of experienced electrical engineers and to form an organization whose sole duty would be to ascertain by field investigation what were the actual power conditions in all the principal industrial centers of the country and to advise as to the best means for remedying difficulties found to exist or likely to occur in 1918 and 1919, the then estimated probable duration of the war.

It was deemed desirable to secure as the active head of the proposed organization an electrical engineer of broad experience in matters connected with power supply and of conceded high professional standing. Among the engineers who had the requisite qualifications Mr. Frederick Darlington, of New York City, appeared to be most available and, as he expressed a public-spirited willingness to assume charge of the organization proposed to be created, his appointment was recommended to the War Industries Board, and after investigation by that body this recommendation was approved. For the requisite technical personnel there were selected a number of specially qualified officers of the Engineer Reserve Corps, and certain other electrical engineers not then in the service were afterwards commissioned as need for them developed, it being deemed advantageous to endow the field agents of this organization with the prestige and authority generally conceded to the uniform of the Army officer in time of war.

This organization was called the power section of the War Industries Board. It consisted of Mr. Darlington as technical head, with Mr. Bulkley and Mr. C. B. Davis, of Boston, and the writer, as associates and advisers, and Capt. William Stanley, U. S. Army, as executive assistant, together with the following Engineer officers to do the technical field work and to collect the requisite data and prepare the corresponding plans and reports:

- Maj. C. F. Lacombe.
- Maj. Malcolm MacLaren.
- Maj. George F. Sever.
- Maj. R. S. Hardy.
- Maj. John C. Damon.
- Maj. A. M. Tinsley.
- Maj. C. H. Shaw.
- Maj. H. R. Leyden.
- Capt. George K. Miltenberger.
- Capt. Lyle A. Whitsit.
- Capt. Robert W. Lamar.
- Lieut. W. E. Heibel.

Mr. Percy B. Thomas, of New York, an eminent consulting engineer, on several occasions contributed his services when problems of special character were involved.

The general scheme for the operation of the power section was to subdivide the country into districts having regard to their industrial character, importance, and relations when considered from the power standpoint, and to make a careful survey of each district for the purpose of ascertaining its exact power resources, the load or existing demand, its probable increase to supply such war necessities as each was

best fitted to produce, and to use this information in the preparation of such recommendations for the administration of the existing supply and such plans for increasing it as in each case seemed necessary or advantageous. This work was most urgent and was first completed in those localities where trouble was actually being experienced. The intention was to make the power section the repository of authentic information as to the power resources of the United States, the adviser of the Government as to the best methods of utilizing the available supply and of supplementing it for any desired purpose, and the liaison between the power industry and the various Government agencies engaged in the procurement of things needed for the vigorous prosecution of the war so far as concerned the power required for their production.

These various functions were to an ever-increasing degree discharged by the power section until the end of the war. Some overlapping and conflict of jurisdiction naturally occurred, but the amount steadily decreased as the power section became better known and was recognized to be a useful as well as a necessary arm of the Government.

The districts in which work was done by the power section were mainly those in which shortage actually existed, and were the New England district; the New Jersey and eastern Pennsylvania district; the southern district, including North Carolina, South Carolina, Georgia, Alabama, and eastern Tennessee; the Pittsburgh district, including eastern Ohio; and the entire Pacific coast treated as a single district. Western New York, because of the international problems involved and the peculiar difficulties of the Niagara Falls hydroelectric situation, was separately handled outside the power section. It should logically, however, hereafter be included in the jurisdiction of any agency that may be created to investigate, coordinate, and regulate, for war purposes, the power resources of the United States.

In each district—and, as stated, these included only the localities where trouble was actually experienced or where it was known that it would probably soon arise—a comprehensive power survey was promptly made, covering the existing power generating capacity and facilities, the exact load, including detailed lists of consumers using more than 100 horsepower, with a statement of the nature of their business or output, the plans or construction under way or contemplated for the early increase of generating capacity, the probable or desirable increases of load having in view the industrial advantages or peculiarities of the locality; and, based upon this information, plans were prepared for increasing the power supply as promptly and efficiently as possible, considering the conditions of the country as a whole and the needs of the war program. In this way it was possible to understand clearly the entire power problem and to coordinate the plans for remedying deficiencies and for supplying future requirements with those of the various agencies, such as the Ordnance Department, the Navy, and the Shipping Board, all of which were placing large contracts for supplies and, in addition, were purchasing on a considerable scale generators, turbines, boilers, and equipment of the very kind actually needed for the power stations it might be desirable to construct or to enlarge. Close and

sympathetic relations with the above departments and with the machinery and boiler section of the War Industries Board were therefore necessary, and the power section at all times attempted to protect the public interest by the maintenance of such relations.

Following the making of these surveys and the ascertainment of the work necessary in each locality, conferences were had with the principal interests concerned, looking toward the construction of these additional facilities. While certain small but valuable improvements were thus secured, in the main it proved impossible to induce the public utility companies to undertake work upon any comprehensive scale, the reason given being their inability to raise the necessary funds upon terms that they felt justified in accepting. Even the War Finance Corporation, a creature of the Government itself, seemed unable to advance the needed funds upon workable conditions, and in the end it became evident that there must be some degree of direct participation by the Government to enable needed extensions of the power supply to be made in those localities where shortage actually existed, or was plainly imminent. There was, however, no general authority of law to construct or acquire power plants or to extend private power plants and to expend public funds for such purposes, and it became necessary therefore to resort to the plan of furnishing assistance through the intervention of that branch of the Government judged to be most concerned in the power supply of the locality under consideration. The manner in which this was done is referred to in connection with the discussion of conditions in the Pittsburgh district. In effect, it became necessary to decide where should fall the duty of furnishing financial help in the localities believed to be in such serious condition as to justify resort to extreme measures, and to arrive at such decision the chairman of the War Industries Board secured a meeting between the Secretary of the Navy, the chairman of the Shipping Board, and yourself, at which it was agreed that the three localities that were in the most alarming condition as to power supply were Northern New Jersey, Philadelphia, and Pittsburgh, and that the interest of the Navy was the preponderating one in New Jersey, that of the Shipping Board in Philadelphia, and that of the Army in the Pittsburgh district, and that in each of these localities the duty of furnishing assistance in installing additional power facilities in accordance with the general plans and recommendations of the power section should be taken up and financed by the corresponding department along the lines of the contract with the West Penn Power Co. Good progress was made by the War Department in preparing contracts for power extensions in the Pittsburgh district. In the other two localities, for one reason or another, but little was accomplished before the armistice made further action unnecessary.

While methods for obtaining increases of power supplies in threatened localities were under consideration, with a view of remedying difficulties, reconciling differences, and securing the most advantageous possible use of existing power resources as well as of securing such advantages as could be had from close and friendly cooperation with such agencies as the Railroad and Fuel Administration, the War Industries Board, etc., it was deemed advisable to have at some central point in each district a representative of the power section furnished with such credentials and instructions as seemed necessary to

enable him to handle the situation. This was actually done with the result that considerable trouble and delay were avoided and much good accomplished not only on behalf of the Government, but also for the individual communities.

From what has been said it will be observed that no large general increases in power supply had been placed in effect at the time of the armistice, and that notwithstanding the organization and work of the power section the country was still, practically a year and a half after the declaration of war, unable to proceed to the execution of a comprehensive program for taking care of our ascertained power needs of the near future. While much was in reality accomplished in the way of developing the facts and preparing an orderly and economical program for further operations, it is, nevertheless, true that we were just beginning, as the war drew to a close, to see our way clear. This was because from April to December, 1917, no single official agency existed to which all power interests and power users could appeal for an investigation of their troubles and for such help as seemed indicated, and that even after such an agency had been created by the establishment of the power section of the War Industries Board it was only an investigating, planning, advisory, and supervisory body at a time when the financial, labor, and business conditions were rendering it increasingly more difficult for private corporations to raise the funds on other than prohibitive terms. These conditions, now well known, were not generally recognized as permanent until the power section took up actively with the appropriate authorities the matter of securing legislation under which the power situation might be adequately dealt with. It took much valuable time to get the desired legislation before Congress, and when finally it was introduced as H. R. 12776, an "Act to provide * * * for the more effective prosecution of the war by furnishing means for the better utilization of the existing sources of electrical and mechanical power and for the development of new sources of such power and for other purposes," owing to the pressure of other business action upon it was slow, so that though it passed the House it was never enacted into law. A copy of the act accompanies Appendix A of this report, and reference to it will furnish a definite idea of the scope and character of the authority which had been shown to be necessary for the proper handling and coordination of the power situation under the difficulties caused by the World War. Authority less ample than therein provided would be inadequate.

The various appendixes to this report describe the conditions that were found to exist in the various districts, and it seems needless to repeat here what the representatives of the power section ascertained and what was done in each individual case. The appendixes tell the story fully and should be consulted.

In a general way the reports may be summarized by saying that a shortage of power existed at the chief industrial centers throughout the United States; that owing to lack of flexible and capacious interconnections between adjacent power systems it was virtually impossible to reduce this shortage by taking advantage of the diversity factor and by releasing for active use part of the installed reserves which interconnection would have rendered safely available; that while existing power systems had planned and started considerable extensions these had been almost entirely discontinued and were

therefore no longer in progress owing to financial conditions, which made such extensions virtually impossible of financing for the private corporations concerned; that no means existed for making extensions and interconnections at public expense with such safeguards as might be deemed necessary for securing reimbursement of all or part of their cost; and that finally no broad comprehensive plans were in existence showing how all existing power resources, steam, as well as hydraulic, should be interconnected, developed, and coordinated so as to serve not only the immediate war needs, but also to supply the general public in times of peace with the greatest efficiency and economy.

These difficulties were to some extent overcome by the intervention of the power section, and its various local representatives did much to relieve serious shortages, to adjust differences between neighboring power systems, to coordinate operations where any degree of interconnection existed and in general to promote the interests not only of the United States, but also of the general public. Due to the almost complete cessation of work on power extensions previously mentioned, to have successfully made any really large addition to our power supply during the time that our war industries were most active would, however, have taken far more time than was actually available in view of the well-known fact that the construction of a large power plant, whether steam or hydraulic, requires at least a year and a half or two years, even under the most favorable conditions.

Having all this in mind, and with a view to promoting preparedness along correct and broad lines, after the armistice, the power section prepared reports setting forth in a general way the plans under which the power resources of certain districts should be developed on broad lines, so as to afford reasonable protection against the difficulties experienced during the World War and at the same time to utilize to the utmost the energy available, both developed and undeveloped.

Accompanying this report there are appendixes describing the investigations made in New England, New Jersey, and eastern Pennsylvania, the Southern States, western Pennsylvania, and eastern Ohio, and on the Pacific coast, all with a view to devising broad plans for the efficient and economical extension of the power resources of these localities so as to supply the anticipated needs of the next five to seven years. These reports, especially those relating to the New Jersey and eastern Pennsylvania situation, the Southern States, and to western Pennsylvania and eastern Ohio, contain much valuable information and go far toward showing the manner in which the power resources of those localities should be supplemented. As a general rule, it is found that future construction should be along the lines of recent evolution and that the best economy and therefore the highest national benefit will result from the construction of large central stations of the steam superpower plant type, supplemented by the development of those hydroelectric resources of the locality that will most efficiently and economically contribute toward supplying the desired increase in the power supply.

It does not seem necessary to repeat in detail the obvious arguments in favor of replacing inefficient isolated small power plants by large steam stations equipped with the most economical devices

known to the art. Very large economies can be attained by reducing coal consumption to the minimum, and the incidental advantages of reducing the demands upon our coal supply and upon our badly strained railroads must be evident. Similarly, it requires no argument to prove that where undeveloped water powers can be shown to be capable of development at such low cost as to permit the delivery of power at figures comparable with the present costs of steam power, it is in the direction of sound national policy to encourage the construction of these hydroelectric plants, particularly in the manner suggested in the reports above referred to where it is proposed to tie the water power plants into large systems containing also one or more steam superpower plants, thereby permitting the economical operation of both types of plants in accordance with their individual peculiarities. For example, in the Pittsburgh neighborhood, already referred to, the report of Capt. Whitsit shows that certain water powers upon the Clarion and Cheat Rivers may be developed so as to carry the peak loads of the very large interconnected system proposed to be established in western Pennsylvania and eastern Ohio, and that when the combined system is thus operated, the unit cost both of the water power and of the steam power is reduced to a very reasonable figure.

Similar proposals are made in the report on New Jersey and eastern Pennsylvania in which Maj. MacLaren shows the advantageous possibilities of building large steam-power stations in the anthracite coal district supplemented further by the development of water power upon the Delaware, Paupack, and Susquehanna Rivers. In this report, as well as in the preceding one, it is shown that the tributary territory must rely very largely upon steam power to supply the great industrial demand. The Southern States are, however, more favored in that the larger part of their power demand may be supplied by the judicious use of existing water-power possibilities, and the report on that section recommends that in addition to interconnecting the large power systems now operating in that territory, there should be developed also certain water-power sites whose use is regarded as peculiarly advantageous for supplementing the existing supply of power and reducing the drain upon our coal resources. The principal water powers recommended to be developed in the Southern States are those at Cherokee Bluff, on the Tallapoosa River, at Bartlett Ferry, on the Chattahoochee River, and at two sites on the Tugaloo, but especial emphasis is laid upon the great economy possible from linking the Muscle Shoals development now under construction under the provisions of section 124, of the national defense act, approved June 3, 1916, with the large interconnected system proposed to be established in the southeastern section of the country. It is especially desirable that consideration be given to the recommendation made in the report on the power situation in the Southern States that the provision that this power plant "shall be constructed and operated solely by the Government and not in conjunction with any other industry or enterprise carried on by private capital," be repealed, for apparently the very large amount of secondary power that may be generated at Muscle Shoals can be used economically only in connection with a large system, affording great diversities as to natural and operating conditions. It seems particularly desirable that attention be given at the earliest possible moment to the adoption of legislation

under which the Muscle Shoals power may take its appropriate place in the southern power scheme.

At the risk of some repetition, it seems profitable to quote extracts bearing upon these projects for power extension and interconnection, taken from a review of them prepared by Maj. Malcolm MacLaren, Engineers, United States Army.

In every instance these reports are directed solely to the primary generation of power and the delivery of this power to the industrial power-consuming centers. The reports do not concern themselves with the question of local distribution from these centers to the various consumers. The ground work for this local distribution is already established by the distributing lines of the existing central station power companies, which are already installed in all industrial and thickly populated areas. The cost of creating power, as set up by the Engineer officers' reports herewith, must not be confused with the cost of power delivered to consumers, as experience has demonstrated that transmission and distribution of power to individual consumers frequently costs more than the generation of power.

As estimates of the construction and operating costs of power plants for future production are the basis of these reports and recommendations, it was necessary to adopt a reasonable and uniform basis for estimating the post-war cost of various works. It was recognized that war-time construction costs were very high and uncertain, and further that future costs must depend very largely on the basic cost of labor, which probably will not, at least for a long period, be as low as in prewar times. In view of all the considerations, the general basis for the estimates submitted, adopted as a probable average for the next five years, represents about 40 per cent excess over the low cost of prewar times. For the purpose of estimating operating expenses following the war, attention was given to increased expenses for mining and transporting coal and for labor, and the cost of power for post-war times is based on these post-war estimates. In estimating the cost of power the charges against capital invested were estimated to include a moderate rate of interest return to the investors and a reasonable allowance for obsolescence or depreciation and for taxes. The aggregate of these charges against capital varied according to the nature of the structures and existing tax rates from a minimum of 10 per cent to a maximum of 13 per cent or 14 per cent. All estimates of expenditures for replacements and repairs were included under operation and maintenance.

The status of the power business in the districts covered by these reports shows clearly the need of adopting a comprehensive policy with definite plans for the construction of unified power systems covering large areas, many of which are interstate in their extent. There should be a close economic relation established between the generation of power, the conservation and transportation of fuel, the improvement of navigable conditions on rivers, and the control of floods. A properly developed system would combine these four operations to supplement each other and laws to control these matters should be enacted to encourage a predetermined and intelligent development on a comprehensive plan for each natural power section and to aid in securing money for their accomplishment.

A clearer understanding of the difficulties in the way of power development on a large scale may be had by considering specific situations as set forth in the accompanying reports. For example, the eastern Pennsylvania-New Jersey power district embracing practically all of the industrial parts of New Jersey, including 180 municipalities, from Hoboken and Newark south and west to Camden, and Pennsylvania, east of the Susquehanna, including Scranton, Wilkes-Barre, Reading, Philadelphia, Chester, and intermediate to and adjacent territory can best be served from one interconnected power system. The most economical way of generating power for this system is with mammoth steam plants burning bituminous coal in the portions of the district centered around Newark, Philadelphia, and Chester, and with supersteam plants burning low grades of anthracite coal in the hard-coal fields and with hydroelectric plants on the Delaware and Susquehanna Rivers, where over 2,000,000,000 kilowatt hours annually could be advantageously developed by water. To properly carry out this work it will be necessary to secure the cooperation of existing electric companies in two States; to secure permits for hydraulic construction in three States, and on the Delaware River where it is a State boundary line, each single development will require two State permits. Right of eminent domain

for condemning transmission line rights of way and for securing lands for flowage and storage reservoirs is not granted by Pennsylvania and New York laws and will be needed for this project; permits for damming the Delaware River, which is classed as a navigable stream, can only be obtained by congressional action; and finally, if these things were all secured by the enactment of new laws and by other means, any corporation which supplied the money and carried out the work would have its rates for power regulated by the commissions of the several States in which the power would be sold. Under this condition there would be no common authority with jurisdiction to establish rates that would secure an adequate return on the money expended for the entire undertaking. To carry out this plan for supplying cheap and reliable power and conserving resources existing laws should be changed and new laws enacted.

Another example of the conditions which restrict unification of power production and interstate development is illustrated in the Southern States report. In this section the recommended plan is to tie together existing power systems to form one big system, to utilize existing generating plants in the order of their efficiency, and to build new plants to supply additional power, using the best water powers available, and to build new steam plants located at coal mines. On the southern rivers, also, it is difficult to obtain satisfactory Federal permits for building dams or regulating the flow on navigable streams. Here also it is necessary to secure the cooperation of diversified power interests of different States and to attract capital to the enterprise. Here, as in the first example, the control of the power business and the regulation of rates rest with the different States of the section that will be served, and there is no common authority to pass upon the financial features of the project as a whole, and to fix the rates to afford protection and profit to the invested capital.

Another complication has been introduced into the Southern States power situation by the Federal Government securing property on the Tennessee River and starting the construction of a large hydroelectric plant at Muscle Shoals. It is shown in the accompanying report (see Appendix E) that Muscle Shoals will be a flow of river development with a very large percentage of second-class power, that the Government's reserve steam plant at Sheffield is much too small to convert all this to prime power and is not as favorably situated for producing cheap power as steam plants located at coal mines, and furthermore, the amount of power that will be available at Muscle Shoals is much in excess of the apparent requirements of the Government. This project is being developed as an independent self-contained system and under the present law the Government is prohibited from selling any part of this power to private interests, or distributing it over the lines of the existing power companies. Exactly the same reasons for the Muscle Shoals power being interconnected and operated jointly with the other power system hold as in the case of private projects, where every recommendation is for interconnection and joint operation. Interconnection would afford a relay to the Muscle Shoals service to help change their second-class power to prime and improve its reliability and economy. The benefit in cheapening power by interconnection and joint operation between Muscle Shoals and the private interests would accrue to both the Government and to the private companies. The unified system which is recommended in the Southern States report to be created by the interconnection and joint operation of private power companies would, if accomplished, afford an efficient means for distributing Muscle Shoals power to diversified industries throughout these States, as well as constituting a source of auxiliary power to supplement Muscle Shoals during low-water stages. Another use of the Muscle Shoals project which should be realized in connection with supplying power to the Southern States, and that was one of the Government arguments for adopting this site, is the gain that will be made for river improvement by the construction of a power dam at Muscle Shoals. This is only one of many instances in the Southern States, and elsewhere, in which joint consideration should be given to river improvements combined with water power developments.

There are two ways in which the Government work at Muscle Shoals, as now being prosecuted, is working to retard public utility power development, and raise the cost of power to industries in the South. A public utility company in Alabama purchased the Muscle Shoals site and spent considerable money in preparing for its ultimate development in connection with their business, and the Government by securing this property for their uses took away from the private company this resource for creating cheap power. The very fact of having this source of power so taken over by the Government, forces the public

utility company to seek other sources of power, which may not be so favorable as this one, and, unless the law is changed, may result in the consumers of the South having to pay more for their power than they otherwise would. The second way in which the Government work at Muscle Shoals is delaying power production on a comprehensive plan is by raising doubts in the minds of investors regarding the return that may be earned by privately developed power in competition with Government-developed power. The officials of public utility companies are loath to recommend investments in generating plants which may eventually come into competition with Government projects and while these same officials would be very glad to make contracts for the purchase of Government power for distribution over their lines at any price that would be favorable as compared with their own cost of production, and to exchange their own steam power or storage-water power to supplement second-class Government power, they do not feel free to recommend large capital investments in new generating plants where the Government is developing a large source of cheap power, which the Government may not need and which may be thrown into their market.

There is probably no other branch of industry in which duplication and division of operating control, necessary to secure competition, works for greater waste and inefficiency than in electric service where economy and reliability are best secured by interconnection and centralization. Under existing laws the comprehensive plans for development set forth in these reports would be almost impossible of execution. There is no Government agency or department empowered to carry on such work; the development of water powers by private capital on Government lands or navigable streams is restricted by conditions that are not workable; special congressional action is necessary to obtain permits for the sale or rental of water for generating power at dams created for river improvement or flood regulation; other laws, both Federal and State, are designed to prohibit monopolistic combinations between manufacturers producing power, thus retarding centralization and unification of generating systems; certain State laws fail to give the necessary right of eminent domain for condemning transmission line rights of way, intrastate and interstate, essential for interconnecting power systems; in most States the regulation of public utility electric business is in the hands of State commissions, which commissions differ in their policies regarding capital issues for public utility electric companies and earnings allowed, and there is no established plan for the regulation of interstate power business.

The financial returns in the electric business, even from concerns that have built wisely for public needs and which have conducted their business efficiently in the past, have not been uniformly adequate to conserve capital investments and maintain dividends. There has been a very common practice on the part of Governmental authorities, both State and municipal, to call for physical appraisals of public utility plants, disregarding capital shrinkage, due to obsolescence or depreciation which involved capital losses that had not been amortized from earnings. Rates were then set up to permit moderate earnings only on the existing physical valuations, with resulting loss to the original investors. In any line of industry in which the development of the art and the growth of the business have been as rapid as in the central station electric power business, it is unavoidable that obsolescence and depreciation shall be very rapid, and the present state of development in this industry could not have been reached without first building the smaller and simpler installations which it is now proposed to scrap or consolidate in the larger and more reliable and efficient systems. The failure of governing authorities to recognize this and to afford protection against loss for work properly constructed and carried on, does not tend to attract investments to the electric business, and electric power companies' securities, which should to-day be among the safest and most gilt-edged investments, are forced to pay high interest rates to secure capital, all of which reacts in increased cost of power to the consumer and retards development on the comprehensive scale that is essential to secure the reliability and economy of production, and the conservation of resources which are necessary to the industrial and social welfare of the country, in which power plays such an important part.

To get cheap and reliable power, to conserve fuel, to improve navigable conditions on rivers, and to control floods, the laws must be so constructed and administered that in each of the natural power districts, the necessary works to accomplish these purposes shall be constructed in one big interconnected system, operated for the mutual advantage of each of the purposes to be attained.

- All State and Federal laws aimed to prevent combinations and interconnections should be modified to exclude public service power companies.

Interest charges on the capital invested in power undertakings, especially for water-power plants, constitute a very large part of the cost of power, and corporations to do the work satisfactorily must obtain large amounts of money at low interest rates. Particular attention should, therefore, be given to the enactment and administration of laws that will encourage capital to invest in electric power undertakings. Conditions which would secure cheap money require that invested capital shall be secured as to principal and interest by the maintenance of rates for power service that will earn an adequate return to conserve or amortize the initial investment and insure reasonable dividends. In the enactment of such laws, ought not provision to be made that future savings in operating costs which may be produced either through improved operation or by the expenditure of capital shall be shared between the power company and the consumer?

As the electric-power business is conducted by private enterprise, it is necessary that the monopolies granted to power companies shall be regulated by governmental commissions. The existing commissions are of State jurisdiction and generally fail to work to a constructive program for unification of systems and centralization of power-generating resources to secure maximum economy for the large districts forming the most economical area for supplying power wholesale. The trouble in this respect is twofold; State jurisdiction is not broad enough for interstate undertakings, and the commissions themselves either do not have wide authority or do not take a broad view of interstate opportunities. * * * For the broad consideration of the problems involved the commissions should be of a judicial nature, with long tenure of office, and removed, as far as possible, from the influence of politics. They should include trained engineers and men experienced in the electric-power business who will appreciate the saving that can be made by building up big power systems that will supplant wasteful and costly isolated plants with superior service and with powers to coordinate electric-power service with river improvements, flood control, and irrigation works.

The preceding quotations represent largely the views of the purely local interests and of the operators of public utilities and are ably and clearly put by Maj. MacLaren. The proposals and suggestions of changes in the existing manner of regarding and regulating the public questions involved are at least worthy of careful consideration, though it is obvious that many difficulties are in the way of their adoption and that the correctness of the policies advocated may be disputed by some who have given these matters long and earnest consideration.

A similar condition exists with respect to some of the advantages claimed for the reservoirs proposed for some of the water-power developments. These reservoirs must either be operated exclusively in the interest of the power development, and in that case their effect on navigation and floods may not be beneficial, or a compromise system of operating the reservoirs must be resorted to, and in that event it may at times be necessary to waste water which might have been conserved had efficiency and economy of power development been the sole consideration. On the average, however, extensive head-water reservoirs should, under careful management, be of some benefit to low-water navigation and as protection against excessive and frequent floods, but in each case the proper system of managing the reservoirs will have to be carefully worked out.

It will also be observed that the estimates of cost for proposed power extensions are based largely on information furnished by private interests. It has not been possible to verify these estimates, nor is the increase of 40 per cent in certain unit prices believed to cover fully the difference between prewar figures and present costs.

The estimates must, therefore, be regarded as only approximately correct.

While the appendixes show in detail the advantages that would result from the adoption of the plans presented for the interconnection of systems and the centralization of power generation, it seems desirable that in a few instances these advantages be summarized and emphasized.

It happens that its commercial and industrial development permits a division of the country into districts, in each of which certain classes of industry having similar needs and conditions are more or less localized, and also that these districts represent units of such considerable area and power demand as to render of doubtful wisdom any proposal seeking to consolidate them into a smaller number, requiring longer and more capacious transmission systems than are herein contemplated. At any rate, the organization of the districts herein proposed and the interconnection, centralization, and expansion of their sources of supply constitute a very large, while at the same time safe, advance over existing conditions. If further consolidation should thereafter prove to be practicable and desirable, great progress will have been made in that direction.

Thus, in New England, where the natural power district embraces the important industrial area from Portland, Me., to Bridgeport, Conn., including Massachusetts, Connecticut, southern New Hampshire, and Vermont, it is estimated that to supply the industrial needs of the next five to seven years 1,400,000 kilowatts of additional generating capacity will be required, of which only 350,000 kilowatts, one-half of the entire undeveloped water power of these States, can profitably be developed by water, leaving the remainder to be developed in large central steam stations favorably distributed in the territory concerned. The compact character of the territory lends itself particularly well to the interconnection of existing systems and to the future expansion in a way most serviceable to the entire community. The introduction of additional water power, the construction of large and efficient new central stations, and the abandonment of the use of isolated or less efficient plants should result in a coal saving for this section running into the millions of tons.

In the New Jersey and eastern Pennsylvania district, including the anthracite coal region, Philadelphia, Chester, etc., interconnecting lines should be built between the principal industrial foci and new generating plants with an aggregate capacity of over 1,200,000 kilowatts installed during the next five to seven years. Under service conditions this increase would produce 5,000,000,000 kilowatt hours annually and would provide not only for the added demand of industry, but also for the energy needed in the electrification of the steam railroads of the region. Favorable sites exist on the Susquehanna and on the Delaware Rivers and its tributaries for the development of over 2,000,000,000 kilowatt hours annually, about 40 per cent of the above total. In this district the development of water power would obviate the construction of steam plants consuming about 2,500,000 tons of coal annually.

In the Pittsburgh district, interconnecting lines are proposed which would unite Pittsburgh, Youngstown, Connellsville, Wheeling, Akron, Canton, Alliance, Massillon, and the neighboring manu-

facturing and coal-mining industries into a single system. Cleveland and Lorain are so close to Akron that they might eventually also be included.

Including Cleveland and Lorain, the total generating capacity of the Pittsburgh district amounts to 773,000 kilowatts and the energy output in 1918 was 2,440,000,000 kilowatt hours. The plant cost of power, including only coal, labor, and plant repair costs, varied in the central stations between 5 and 25 mills. Coal consumption per kilowatt hour varied between 1.8 pounds and 9.2 pounds, the lower figure being that of the most efficient and modern superpower central station and the higher that of the small and antiquated and inefficient central plants. By replacing the worst of the older plants by steam plants of the superpower type, an annual saving of 796,000 tons of coal might be made in this district alone, and the money saving would be nearly \$7,000,000 annually.

But there are also many isolated power plants in this district. Omitting those in the larger steel companies, they total about 700,000 kilowatts of generating capacity, of which 460,000 might be economically replaced during the next five to seven years. Considering the diversified character of the isolated service, this would add 205,000 kilowatts to the peaks of the central systems, and it is figured the change would result in a coal saving of 3,250,000 tons and a money saving of \$12,000,000 annually.

Having regard now to the generating equipment in the major iron and steel companies of the Pittsburgh district, amounting to about 800,000 kilowatts of capacity, and allowing for the use of by-product gas and waste heat, it is not likely that more than half this demand could be supplied by a central system. Allowing for diversified use, this would increase the central peaks by 180,000 kilowatts and a further very large coal saving would result.

In order to meet increased demands of present customers to replace inefficient isolated plants and to supply new industries and to serve steel companies now generating their own power, it is estimated that during the next five to seven years power-generating equipment adequate to supply 3,000,000,000 kilowatt hours annually should be installed, calling for about 730,000 kilowatts of new machinery. The power required for electrifying all the railroads of western Pennsylvania and eastern Ohio would be 2,400,000,000 kilowatt hours annually, calling for a plant equipment of 500,000 kilowatts capacity, but the transformation of the railroads from steam to electric operation would be so costly that it is not for the moment considered to be practicable, and is therefore no further discussed.

To furnish the additional supply of 3,000,000,000 kilowatt hours which it has been stated above will be needed at the expiration of the next five to seven years, a plan is presented in Appendix B for extending certain highly efficient central stations of the superpower type for completing one such station now in progress and for enlarging another, but the plan also takes due note and proposes efficient use of water-power possibilities on the Clarion River in Pennsylvania, where 420,000,000 kilowatt hours may be developed in a year of extreme low flow, 650,000,000 kilowatt hours in an average year, and of course still more in a year of high discharge, and on the Cheat River in West Virginia, where it is estimated that 870,000,000 kilowatt hours may be had in a minimum year and 1,350,000,000

kilowatt hours in one of average flow. Taking the minimum figures about 1,300,000,000 kilowatt hours could be furnished by developing the power of these two streams, thereby saving at least 1,000,000 tons of coal each year. By a proper combination of these hydroelectric developments with interconnected steam plants, the former may be operated under full load and with maximum possible economy while the steam plants take care of the variable portion of the demand and their fuel and labor costs correspondingly curtailed. On the other hand, the existence of the steam capacity permits the freer and more complete use of stored water, so that the situation is one that justifies the most careful study and consideration not only on the part of the power interests here proposed to be combined into a single great system, but also on the part of the public authorities concerned, especially as on both rivers the storage reservoirs proposed will undoubtedly afford some alleviation in case of floods and may be beneficial to navigation during low-water periods.

In the Southern States it is proposed to combine the major plants of Tennessee, Alabama, Georgia, and the Carolinas into a single system. In Alabama, Georgia, and Tennessee the interconnection of five existing systems and the development of new generating capacity producing about 1,000,000,000 kilowatt hours annually comprise the major part of the improvements proposed, this amount of power being nearly sufficient to supply the additional requirements of the next five to seven years. A gain of over 100,000,000 kilowatt hours annually will also result from the interconnection and the more diversified use of energy now available. Of the additional power, 450,000,000 kilowatt hours would be produced in a year of low flow by a single new hydroelectric development proposed, and in a normal year the output of the same plant would be about 700,000,000 kilowatt hours. This single new water-power plant would therefore, if built, save between 400,000 and 630,000 tons of coal each year, and assuming the remainder of the program was followed and further water power developed, the total coal saving possible under the plan outlined in Appendix E would in periods of average rainfall be close to 1,000,000 tons annually.

Without entering into further details, it may be said that the interconnection of the systems and the establishment of the power districts proposed together with the development of the water powers described would not only adequately and economically provide for the power needs of the coming five to seven years, but would at the same time permit a saving of some millions of tons of coal now needlessly or wastefully used and when finally completed would either save or render unnecessary the burning of 10,000,000 tons, or more, of coal annually. The difficulties caused by coal shortage in the winter of 1917-18 are still fresh in our memory, and it hardly seems necessary to urge that plans which will eventually result in so large a saving of an exhaustible natural resource, fuel, in labor, and in transportation, while at the same time making efficient and profitable use of an inexhaustible natural resource, water power, are obviously of such national value and importance as to justify their most serious consideration. These plans can not, however, be placed in effect without legislation, and the passage of a law to permit the development of water power upon terms fair alike to the public and to the interests specially concerned is indicated as

the first and most important step, one which will go far toward relieving the people from their dependence upon fuel whose production is so subject to interruption and whose availability is so closely connected with the uncertainties of the operation of an over-taxed transportation system.

It will be evident from what precedes that, unless steps are taken to profit by the lessons of the past and to avoid the difficulties that we had to contend with, the immense expansion of industrial activity incident to our participation in any war of modern type is liable to cause again the troubles that were experienced in the World War.

We were taken by surprise by the shortages that finally became evident and we were without really effective means for curing them. Eventually, we worked out a remedial program but this consumed much valuable time and the delay might easily have been very damaging.

There was conflict of purpose, interest, and authority on the part of various public agencies, and lack of unity of policy. What we need for our future protection is an exact knowledge of the amount of electric power available, its location, the means by which it is produced, transmitted, and distributed, the extent and manner of its use and the products to which it is applied, the amount, character, and probable time of completion of extensions in process of construction and the programs for future development, showing particularly what is proposed and the probable time of beginning and completion. We need also dependable statistics and information as to the growth of demand for power in each locality, and, based upon our recent experience, we should be able to compile figures showing just how much power was consumed by our recent war-time activities, and to estimate from time to time what change, if any, should be allowed for in our power requirements due to the evolution of the art of war. Definite and permanent arrangements should be made for compiling this information and a policy should be worked out under which, in the future, to handle the power situation so as to avoid unnecessary difficulty, misunderstanding and interference.

The increasing tendency to abandon isolated and relatively small power plants and to resort to the more economical, dependable, and flexible service of large public utility companies supplying considerable districts from power stations of the most efficient type, interconnected among themselves and also joined by proper transmission lines with adjoining power systems causes the matter of assuring an adequate supply of power, always vital, to assume an evergrowing importance in any scheme of preparedness, especially if, as seems likely, the electrification of railroads is undertaken upon any general scale. While it is difficult to say that any single national resource is fundamental, it might well be argued that power supply comes very close to being so, and therefore our future policy regarding it must provide for complete harmony, coordination, and comprehension among the various interests concerned. These are, first, the public utility companies; second, those branches of industry that supply the vital elements in any proposed plan of power increase, such as boilers, engines, steam and water turbines, generators, switchboards, wire, cable, and, in fact, all equipment needed for building power stations and transmission lines; third, the governmental agencies that, upon the outbreak of war and during its prosecution,

will express our war needs in the form of contracts and purchases calling for production upon a greatly heightened scale, these being the War Department, the Navy Department, and, if it continues to exist, the Emergency Fleet Corporation, with their various subdivisions or bureaus, each of which during the late war supplied its requirements with greater or less disregard of the needs of the others and of the real interests of the Government. The policy regarding power supply should be made known and its observance made mandatory, and, particularly, the right to requisition power should be limited to the same agency that, in time of war, may be delegated to enforce the power policy of the Government. A proper priority program for distributing power should be set up, agreement should be reached as to the relative importance of fuel for steam power stations as compared with the needs of such as the railroads, the steel mills, steam vessels, etc. This problem of fuel would, of course, concern any agency, such as the Fuel Administration, that might be created to handle it, and its policy as to priority of supply should be framed with adequate consideration of the needs of the power industry as a whole, and of its place and importance in any logical war program. This is a very important matter and it must be provided for. Finally, the legislation probably needed in a war emergency should be studied in advance and, if possible, enacted during times of peace so that it may be available immediately on the declaration of war.

The collection of information and statistics and the preparation of plans and projects for supplying war needs are essentially engineering tasks, and it seems fitting that they be assigned to the Chief of Engineers of the Army who could readily take the necessary steps to secure information upon which to base the desired power policy and keep the work up to date. For this purpose, he has now at his disposal Engineer officers stationed at or near every industrial center in the United States and he can call into active service for several months each year, as needed, reserve Engineer officers who are specialists in matters relating to the generation and distribution of electric power. The details of the work to be done are described herein and the requisite instructions can readily be based upon what precedes. Much valuable help might be had from the Census Bureau which now collects power statistics and would, no doubt, be willing to arrange the information in the form best calculated to be useful for war purposes.

Due to the termination of the writer's connection with the power section early in September, 1918, and his subsequent absence in France at the time when the work of the section was being closed and its personnel scattered, the preparation of this report has been unduly delayed. Much interest in the subject matter has been manifested on the part of the electric power industry generally, more especially so by the various individuals and corporations that furnished the details upon which the plans presented in the appendixes were based. It is believed that the report is of such general value as to justify the printing of an edition of 300 copies and that, when printed, it should be distributed among those who have applied for it, a list of whose names is now on file.

In closing, it seems fitting to make more specific acknowledgment of the valuable and painstaking services of the members of the power

section, particularly those of Mr. Frederick Darlington, Mr. C. B. Davis, Mr. R. J. Bulkley, and Mr. Percy B. Thomas, all of whom, under trying and difficult conditions, cooperated in setting up a practical solution of a new and Nation-wide problem. It goes without saying that the Army officers whose names have already been mentioned rendered always faithful and efficient service of a very high order, of which this report presents a somewhat inadequate idea. Especial mention should, however, be made of the services of Maj. C. F. Lacombe, who came to the power section at its very beginning and helped notably in its organization, and who prepared the report, which, in abbreviated and revised form, appears herewith as Appendix A.

Very respectfully, your obedient servant,

C. KELLER,
Lieutenant Colonel, Corps of Engineers.

[First indorsement.]

OFFICE CHIEF OF ENGINEERS,
December 22, 1919.

To: The Secretary of War.

Subject: Power reports.

1. Submitted. This is a report submitted by Lieut. Col. C. Keller, Corps of Engineers, describing activities of agencies of the United States during the World War in the regulation and allocation of electric energy generated in and near Niagara Falls, N. Y., as well as of the organization and operations of the power section of the War Industries Board, which handled analagous problems at other localities where power shortage and other power difficulties occurred.

2. This control was exercised originally under the direct instructions and with the personal knowledge and approval of the Secretary of War; and as most of the work was done by officers of the Corps of Engineers, these matters finally came under the cognizance of the Chief of Engineers.

3. It will be noted that the report presents plans for interconnecting existing power systems so as to form a number of so-called power "districts," and for supplementing their power resources during the next five to seven years by the development of water power upon the greatest profitable scale at certain advantageous localities, the remaining necessary power to be generated in steam stations of the super-power type. These proposals are elaborated in the appendixes to the report and appear to merit careful study.

4. In addition, Col. Keller urges the advisability of creating a continuing governmental agency, which, having in mind the power difficulties that arose during the war, will collect and keep currently correct the information which, during the war, it was found desirable to have. He outlines a plan for doing this work, which, with the approval of the Secretary of War, the Chief of Engineers is prepared to place in effect.

5. The report contains information that is of widespread interest, and I therefore concur in the recommendation that it be printed in full, with its appendixes.

FREDERIC V. ABBOT,
Colonel, Corps of Engineers,
Acting Chief of Engineers.

APPENDIX A

**Report to the Chief of Engineers, U. S. Army
Washington, D. C.**

**Submitted by Major CHARLES F. LACOMBE
Engineers, U. S. Army**

REPORT TO THE CHIEF OF ENGINEERS, U. S. ARMY.

INTRODUCTION.

Among the primary necessities of the Nation in the late war was power for the production and manufacture under emergency conditions of the needed raw materials and finished appliances of all kinds.

With the declaration of war the demand for these necessities became imperative, and the delivery required under the spur of the life and death hazard of war became that achievable only by the utmost human endeavor.

One of the main agents in the reduction of the time required for manufacture is an ample and reliable supply of power. Under emergency conditions such supply of power becomes one of the controlling factors. This report deals with this fundamental requirement of the war program and attempts to describe the procedure undertaken to provide for it.

The supply of power in the United States is provided from two sources, one, by individual prime movers, either hydraulic, steam, or gas driven, limited to a particular factory or works, or to several contiguous to each other; in the aggregate this is the largest source. Its continuity of power supply effects only the individual process, factory, or group concerned, and depends primarily on a continuous supply of fuel or a continuous supply of water and the reliability, maintenance, and operation of its machinery.

The other source of supply is the central electric power station which delivers power to a great number of users, both large and small. The continuity of this supply thus affects the product of a community or district rather than of a single process or works. The reliability of this public utility service involves not only the elements controlling the individual plant but many others.

The supply of fuel to the individual power plants, as well as to the central stations, was controlled during the war by the Fuel and Railroad Administrations, and became one of their main problems. With this matter the War Industries Board had little to do. Its principal duty in power supply began with the public utility power station supplying electric power.

This report, therefore, is limited generally to this central or public utility method of power supply, the conditions governing it, the shortage of the supply caused by the demands of the war, the efforts made by governmental agencies to fill the deficiency and their limitations, and recommendations of what should be done if a similar emergency arises in the future.

PART 1.

CONDITIONS EXISTING IN THE POWER INDUSTRY DURING THE WAR OF 1914-1918 BEFORE AND AFTER OUR ENTRANCE.

To present a correct view of the conditions governing the supply of power by public-utility power plants during our participation in the war, it is necessary to explain those prevailing from 1914 to 1917 prior to our entrance into the conflict, especially the unusual business and economic difficulties affecting public utilities from that time to the present.

At the time of our entrance into the war power supply was not one of the problems which attracted attention, because in April and during the summer months following the decreasing seasonal load prevented noticeable shortage. It is probable that it was thought the public utilities could provide power by a process of continuous expansion, and little consideration was given to the cost and effort necessary to do this.

The great necessity for the additional supply of power in large quantities required by the extraordinary demands of war for quantity production was not known or appreciated. The real importance in the industrial world of the great public power station was not recognized generally, and one reason for it is that the entrance of the public-utility companies into power supply has been a development of recent years. It may be said broadly that it is only in this country that large power companies have taken the place they are now filling in industrial life.

Since the end of the last century, when the economic transmission of power in large units over long distances was demonstrated, and the early part of this one, when the steam turbine and automatic fuel-feeding devices were introduced, the electric companies have been passing through a process of development, not yet complete, from furnishing light and small amounts of power for fractional parts of a day at comparatively high rates to supplying large units of power continuously over long periods of time at low wholesale rates. It is this latter class of power supply that proved to be greatly needed by the war program of production. Plants of the central-station public-utility type did not exist except in this country, and perhaps in Germany. The lack of plants of this character in England was particularly noted in official reports on the subject. Not all of the existing central-station electric companies in this country, however, had recognized this new field or completed their program of development to meet its requirements.

The condition of the power industry at this time was not altogether favorable for easily meeting a sudden demand for more power. In 1914, as will be shown, owing to the business depression caused by the outbreak of the war in Europe, the demand for additional energy on the central stations of the country was much lower than usual. The demands for war munitions began to make themselves felt in 1915, and from that time until 1917 a steadily increasing demand showed in the returns from the central power stations of the country.

The best statistics obtainable are from the Electrical World, and from them the following table is derived:

Statistics of power industry, 1914-1918.

Year.	Kilowatt-hour output.	Amount increase over previous year.	Per cent increase over previous year.	Gross income.	Amount increase over previous year.	Per cent increase over previous year.
1914.....	16,604,000,000			\$336,800,000		
1915.....	18,401,110,000	1,797,110,000	10.82	360,860,000	\$24,070,000	7.14
1916.....	22,738,000,000	4,336,890,000	23.5	414,370,000	53,500,000	14.83
1917.....	26,736,700,000	3,997,700,000	17.5	474,424,000	60,064,000	14.46
1918.....	29,512,350,000	2,776,650,000	10.87	529,010,000	54,586,000	11.50
		12,908,350,000	77.74		192,210,000	57.06

If the United States census figures of 1912 are used, a gross increase in output from 1912 to 1918 of 17,980,000,000 kilowatt hours, or 155.8 per cent, is shown.

The effect of the war is clearly shown. With 1915 there began a great increase in demand, which culminated in 1917 and 1918. In the latter year it was not fully met because of lack of generating capacity, the available spare capacity being nearly exhausted in 1917. The output at the end of 1917 and beginning of 1918 was also affected by a coal shortage and a severe winter, retarding industry. The relatively lower increase in gross revenue for the corresponding increase in output is due to the fact that the new demand was for power in bulk for manufacturing purposes at lower rates than the demands of average years under usual conditions. Thus the gross revenue per kilowatt hour decreased with each year. It was 2.028 cents in 1914, but in 1918 was only 1.79 cents. A diagram attached shows the comparative changes as percentages of increase of each year over the preceding one.

NOTE.—It was hoped to obtain reliable figures of a sufficient number of representative companies to permit similar diagrammatic comparisons of net revenues. This proved impossible. Such returns as were obtained, however, showed decided decreases in percentage of net return as compared with previous years. The effect of these decreases, however, can be shown by the losses in value of the securities of standard power companies during the period of the war when many other industrial corporate securities were appreciating in value.

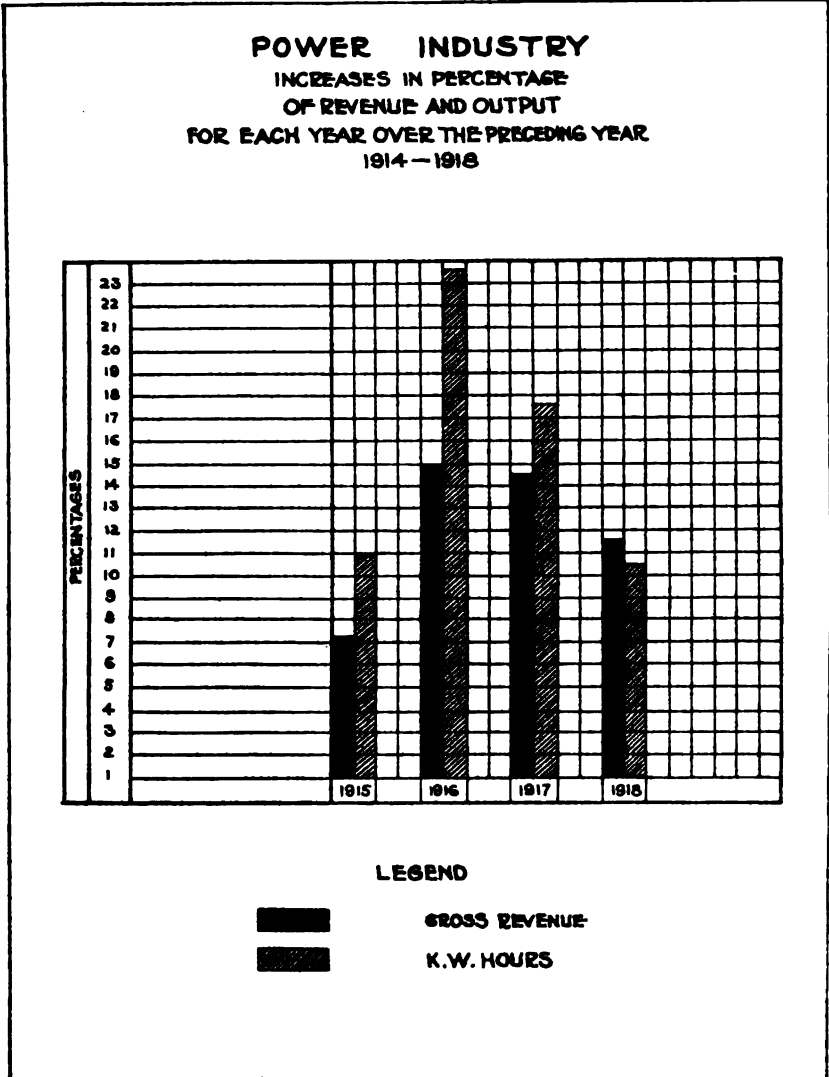
Values at certain dates.

Name of company and bond.	Prewar June 27, 1914.	Before our en- trance, Mar. 21, 1917.	After our entrance.		After the war, Feb. 15, 1919.
			June 30, 1917.	Sept. 20, 1917.	
Kings County, N. Y., Electric, first four, 1940.....	83½	82½	77	(1)	80
Portland, Oreg., Railway, Steam & Power, first and refund sinking fund, five, 1942.....	93	77	75	(5)	74½
Tri City Railway & Light, Davenport, Iowa, first five, 1923.....	97	100	97½	(4)	95
Detroit, Edison, first collateral trust, five, 1923.....	100½	103½	101	99½	96
Pacific Gas & Electric Co., unifying and refund, five, 1927.....	92½	99½	96½	(6)	86
Union Electric Light & Power, Cincinnati, first five, 1932.....	100	100	(2)	(7)	91½

- * No bid offered at 72½.
- † No bid.
- ‡ No bid offered at 75.
- § No bid offered at 97.

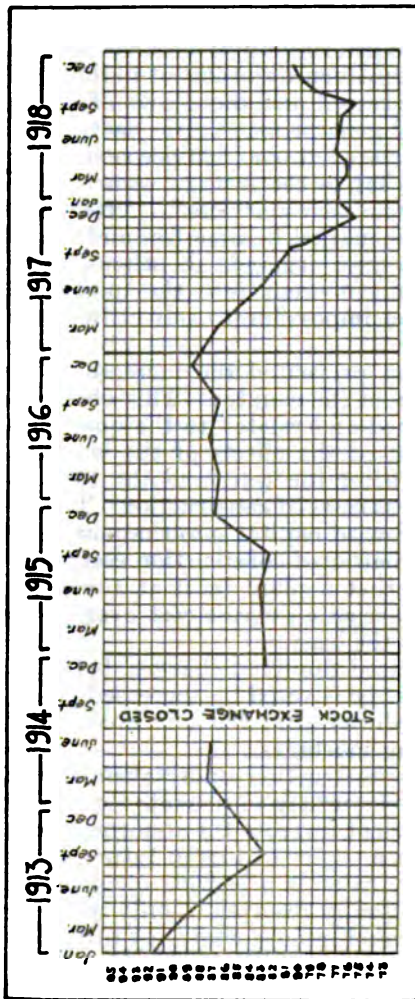
- ¶ Bid.
- ‡ No bid offered at 96.
- § No bid offered at 97½.

Many central station companies had arranged programs of expansion to meet their usual periodic requirements for additions and some large additions were completed in time for the emergency. Many of these projects, however, were suddenly disturbed and in many cases broken up completely by the sudden demand made in 1917 by the



Government on the electrical machinery manufacturers for turbo-generators of all sizes. Many were for propulsion purposes, but a number of large generators were for Government munition plants. As these demands of the Government required priority they at once affected the time of completion and delivery of generators for public power plants, and also their cost which immediately began to rise.

The results made themselves felt in 1917 and by the middle of 1918 had extended practically to all the appliances and auxiliaries necessary to the construction of power plants, and great delay and embarrassment were caused construction then in progress.



TREND OF THE BOND MARKET 1913-1918. This graph was produced by using the "New York Times" computations. In order to obtain this comparative index the weighted-average method was used. The average price of twenty-five Rafts of various classes was combined with the average of eight Industrials, six Public Utilities and one Municipal.

THE NATIONAL CITY COMPANY.

Control of the program of manufacture of power machinery and appliances was assumed by the Government through the War Industries Board about May, 1918, and the efforts of the power and equipment section of the board were thereafter devoted to the accelera-

tion, regulation, and distribution of production until the end of the war.

Furthermore, the cost of all materials and supplies going into the construction and operation of central power plants increased very rapidly from 1914 to the end of the war. Copper rose from 11.3 cents to 36 cents a pound in 1917; structural-steel shapes from an average price of 1.16 cents to 3.66 cents in 1917, and other steel products increased in price from four to six times over 1915. Fuel more than doubled in cost in many cases. Labor, under the war demand for increased output as well as for men for the Army, became more and more difficult to get, the supply became irregular, and wages increased greatly. In consequence the cost of building central station power plants greatly increased and there was, of course, a large increase in the expense of generating electric energy. The increased cost of building was estimated at over 100 per cent.

The money market, so far as the issue of securities of public utilities was concerned, became very restricted. After the reopening of the exchanges in 1914 the market became less and less able to absorb them on account of the war demands in other directions, until in 1917, when the Government went into the money market to sell Liberty bonds, it became impossible to sell utility securities except at prohibitive discounts.

Still another condition prevented the increase of central power-station capacity throughout the country. This obstacle arose largely from the causes mentioned and related to the question of increasing compensation on account of the effects of the war, the permanence of these rate schedules after the war, and the method and rate of amortization of war excess costs of construction. These problems had a decided effect on the flow of capital into the power industry.

Referring first to the matter of construction costs and their amortization, it has been seen that a plant built at advanced construction prices during the war carried an excess cost over prewar conditions of a hundred per cent at the least.

This excess cost increased the fixed charges, both for interest and amortization, which must be covered by increased rates. These fixed charges would not be reduced after the war except in part, possibly by refunding outstanding mortgages.

In consequence, were construction undertaken, it would be necessary to increase rates permanently to provide for the increased capital charges. This permanent increase for abnormal costs might prove troublesome and perhaps a source of loss in future years.

The raising of public rates is a serious question with a public-utility company and is usually resorted to only when very necessary. These rates may be increased in most States by filing a new scale with the commission regulating such matters, and they go into effect after a prescribed period of notice has elapsed, provided they are not questioned during this period. In some States rates may be suspended by action of the corresponding regulatory commission. At any time a rate scale can be called into question by the public and an inquiry as to its fairness had at the expense of the State. The necessity of showing cause and the burden of proof are on the contestant. Maximum rates set by the legislature of a State, it is understood, can be questioned only by proceedings before a competent court on the ground that they are confiscatory.

General rate increases are usually subjected to careful and elaborate investigation by the commissions having jurisdiction, expensive and lengthy procedure, valuation being the usual rule.

For these reasons and the further one that increases in rates are very apt to arouse public prejudice and antagonism against the utility, this method of relief from increased costs of production is generally resorted to only when the imperative necessity for it is fully and publicly established.

Under the conditions incident to the war, however, a number of utilities selling energy found their costs of production mounting rapidly and net profits diminishing below the fair return which they should earn upon their investment. Thus increasing business increased the gross earnings, while net earnings steadily diminished, and this larger business as it approached the ultimate capacity of the plant brought disadvantages of service and dangerous risks of breakdown, which might well prove disastrous to the whole business of the plant. In such cases it was necessary, therefore, to apply for an increase in rates even at the risk of opposition and unpopularity.

The question of increasing the size or number of plants to develop the power demanded became grave and difficult, particularly as the duration of this demand was quite uncertain. As construction costs and the cost of money were abnormal, and net earnings decreasing, due to increasing operating costs, the rate of return which would be allowed on additional investment became a controlling factor to the extent that new capital was not to be had without adequate assurances as to the soundness of the enterprise.

To sum up briefly, in our first year of war the power industry was confronted with a heavy demand for additional output of power, superimposed on an increased production of 38 per cent supplied in 1915 and 1916, and under the following conditions making fulfillment most difficult:

1. Selling price of product fixed by regulation. Relief restricted and doubt as to its permanence.
2. Very greatly increased cost of operation.
3. Very greatly increased cost of appliances and construction.
4. Possible decrease of net earnings if these conditions continued in succeeding year.
5. Inability to get machinery and supplies in time to meet the demand of the Government's war requirements.
6. Market for securities unfavorable during preceding two years and practically closed in 1917 on account of sales of Government war bonds making funds impossible to obtain except at discounts involving certain loss.

With these conditions only the most prosperous and foresighted companies could cope and so provide additional power; others could only look forward to increased load at an increasing cost of production with possibly decreased net return until the limit of their capacity had been reached and they would then find themselves in constant danger of disastrous interruptions to their service.

It was from six to nine months after April, 1917, before these conditions became known and investigations were begun. When completed, it was found that the industry was called on for its share of increased service without the sources of relief at the command of other industries that by their circumstances had promptly compelled Government attention and assistance, or could meet additional war costs by freely increasing prices for their products.

PART 2.

DESCRIPTION OF THE GENERAL SHORTAGE OF POWER AND EFFORT MADE TO ALLEVIATE THIS CONDITION.

While the shortage in 1917 was precipitated and increased by the very severe winter of that year, which decreased the hydraulic-power supply and created a shortage in fuel, it is nevertheless true that regardless of weather and fuel in several of the great industrial districts of the country a real shortage existed in power supply and in the plant capacity necessary to meet it. This can not usually be expressed in exact figures because the fact that a known shortage existed deterred possible users from coming forward. One example will suffice to illustrate conditions. In the Niagara Falls and Buffalo district through the entire war the chemical and steel industries had a capacity of machinery and plant on hand available for production purposes about 20,000 horsepower more than the power they could obtain when the power plants at and near that district were running at 100 per cent of their capacity.

Any exact statement of the industrial sections that suffered from power shortage from the fall of 1917 through the summer of 1918 is difficult. The shortage developed slowly. In the late summer of 1917 the Canadian Government was confronted with demands for additional power at and near Niagara Falls, and the advisability of decreasing the export of power to the United States was at once suggested. But power generated on the Canadian side of Niagara Falls and exported to the United States was a very important source of energy in the Niagara Falls-Buffalo district. Complaint was therefore immediately made to the Secretary of War, who directed Mr. Robert J. Bulkley, head of the legal committee of the War Industries Board, to investigate the matter and secure an equitable adjustment with the Canadian Government. The Canadian Government was represented by Sir Henry Drayton, who had been appointed power controller for the purpose of dealing with the power stringency at and near Niagara Falls. A provisional arrangement was arrived at under which, in view of the fact that Canada and the United States were allies in a common cause, it was agreed that no reduction should be made in the amount of power exported from Canada until after a careful detailed investigation of the uses of Niagara power on both sides of the border, a corresponding ascertainment of the strict war needs of the industries and communities in that locality, and a redistribution of the power available on each side so as to supply most fully the respective war industries in the order of their importance. The appointment of a director of power was also proposed, so as to insure the limitation of the use of power to war industries. On

reporting to the Secretary of War this proposal was approved, and he appointed Mr. Bulkley and Brig. Gen. (then Col.) Charles Keller, of the Corps of Engineers, to represent him jointly in this district.

The necessary careful examination into the use of Niagara power was made in November, 1917, the force of the United States Lake Survey being used for the field investigation, and agreement finally concluded with the Canadian authorities as to a common policy for power supply and its use in the Niagara district.

A power shortage began to develop in Pittsburgh in November, 1917, and the priorities committee of the War Industries Board, after some meetings at Washington and some correspondence, asked Mr. Bulkley to act for them in the matter. Mr. Bulkley went to Pittsburgh in December and adjusted the situation there.

President McCall, of the Philadelphia Electric Co., in December called attention to the probable power stringency in Philadelphia, Pa. New Jersey suffered from a shortage in fuel and power, and New England also began to run short early in the winter. In January, 1918, Pittsburgh again became troublesome, and a disastrous ice jam at Niagara cut off a large part of the hydraulic power supply at that point.

In other words, a shortage of power supply threatened in many places and a thorough investigation was begun by the power section of the War Industries Board, an agency newly created for the purpose of taking cognizance of all questions relating to the supply and distribution of power for industries manufacturing articles essential to the prosecution of the war. The creation of this board was suggested by Gen. Keller and authorized by the Secretary of War. At its head was Mr. Frederick Darlington, of New York, an eminent electrical engineer, whose public spirit, high character, accomplishments, and professional standing peculiarly qualified him to act as the technical head of the organization with which Mr. Bulkley and Gen. Keller continued to act in all matters involving large questions of public policy. The working force of the power section consisted of officers of the Engineer Reserve Corps selected because of their known qualifications as electrical engineers. Under the direction of Mr. Darlington, these officers performed the work of investigating power conditions throughout the country. This investigation showed that the sections particularly affected by war demands were the industrial districts, which may be designated as follows:

LOCATIONS OF SHORTAGE.

Niagara Falls, Buffalo, and the territory depending on power supply from Niagara Falls, along the lines of the Niagara, Lockport & Ontario Power Co., in northwestern New York, as far east as Rochester and Syracuse.

Pittsburgh and neighboring cities, including Wheeling, Canton, Massillon, Alliance, Akron, Youngstown, and Connellsville.

The New England States, particularly Massachusetts, the southern portions of Vermont and New Hampshire, southwestern Maine, and Connecticut.

The State of New Jersey.

Philadelphia and eastern Pennsylvania.

Baltimore, Md., and Wilmington, Del.

The Pacific coast.

Other smaller sections developed acute shortages during the year, notably:

Several localities in the Southern States.

Norfolk and Hampton Roads.

The Virginian Power Co. and the Appalachian Power Co. in West Virginia.

Bucyrus and Mansfield, Ohio.

Lorain, Ohio.

Little Rock, Ark.

CAUSES OF SHORTAGE.

The main causes for shortage of power supply in these districts, which it will be noted covered a large part of the industrial area of the country, were:

(1) Shortage of fuel principally caused by lack of storage and in some degree possibly by deficient railroad transportation or inadequate production.

(2) Shortages of water power due to adverse weather conditions in both the winter and summer of 1917-18.

(3) Lack of capacity of central electric-power plants to meet the extraordinary war demand. This was due to reasons already described.

The first of these causes could have been prevented if, in 1917, ample storage had been provided in sections where transportation was subject to congestion as in New England.

The second cause it was not possible for the power interests to prevent.

The third cause could have been prevented if it had been foreseen or realized earlier; but, further, might have been partly relieved by the end of 1918 if the proper action could have been taken early in 1918, when investigation first disclosed this contributory reason for the shortage.

As the separate several cases of power shortage developed from the fall of 1917 to the spring of 1918 they were met by various methods and, in certain specific cases, by direct aid in the form of power machinery installed in connection with contracts for particular products required by the Army, the Navy, or the Emergency Fleet Corporation, the cost of this machinery being absorbed to a greater or less extent in the cost of production. These arrangements were not, however, at first referred to any central authority for information and advice. There was, in fact, no such authority until the power section of the War Industries Board was organized, but when this had been well established such references were made and good results followed. In the fall of 1917 so many complaints of power insufficient to handle contracts placed by the Army in certain localities were received by the Power Administrators that an order was issued by the Secretary of War on December 28, 1917, and another on March 25, 1918, prohibiting the placing of further orders for Army supplies in the localities concerned except with the approval of the War Industries Board. These orders remained in effect until the end of the war. Copies are appended marked "Exhibit A" and "Exhibit B."

The fuel situation became very acute during the severe winter of 1918, particularly in New England and along the Atlantic coast, not only on account of the difficulties of transportation by rail but also because the supply of fuel to New England normally is largely by water, while the Emergency Fleet Corporation and the Navy had taken over practically all coastwise shipping facilities, tugs, barges, etc., for other purposes, and therefore supply by this means was greatly restricted. The cold winter and the abnormal quantity of ice in the harbors also served to hinder water transportation.

FUEL ADMINISTRATION MEASURES.

Coal supply by rail was also greatly impeded as far south as the Eastern Shore of Maryland by the congestion of freight which had to pass through the five great rail portals to the Eastern Atlantic coast, until on June 11, 1918, the Fuel Administration issued a circular recommending that work requiring the use of more fuel be excluded from the area east of a line drawn north and south near the eastern boundary of the State of New York, from Canada to near Schenectady, and thence through Binghampton, Williamsport, Altoona, Shippensburg, and Baltimore.

This recommendation prevented orders going to some sections like New York City, where power was plentiful. In spite of all these restrictions the impossibility of manufacturing certain articles in other sections, the urgency as to time of delivery, etc., forced many increases of power demand in the restricted territory and made additional supplies of power there even more urgent.

The Fuel Administration also took up, through its Conservation Division, an investigation of the possibility of saving fuel by several methods involving—

(a) The shutting down of small and also old and inefficient plants and the transfer of their loads to large and more efficient plants.

(b) The interconnection of power plants by transmission lines to utilize load and diversity factors to better advantage.

(c) Substitution of water power for steam power. It will be noted that this was essentially a duplication of studies already inaugurated by the power section.

ARMY, NAVY, AND SHIPPING BOARD INVESTIGATIONS.

The Ordnance and Construction Divisions of the Army made a number of investigations as to power required for manufacture of guns and armor, as well as for nitrate and powder plants. The Navy Department also carried on similar investigations.

MAIN PROBLEM.

The proper solution of the power problem should have as to its object to develop power at points best situated for its production and application, to produce it in large units of high efficiency so as to conserve fuel, machinery, and labor and material for construction; to increase the available supply by cooperation between and interconnection of stations; and to administer the supply of power so developed as to give the maximum output of war supplies required by the Government. This was required to be done in the

shortest possible time. Time in war is not evaluated in money, but in terms of lives as time is gained or lost in equipping armies for effective action. Particular attention is drawn to this point for the reason that it was the dominant factor in the engineering plans recommended for furnishing additional power in several of the districts where shortage occurred. In other words, methods and plans were adopted for cooperation and interconnection which, while valuable or convenient in time of peace, were justifiable mainly because of the war. It took this emergency to show how much these methods could accomplish in economy of production as well as of first cost due to less reserve equipment being required.

MAIN DIFFICULTY ENCOUNTERED AND PARTIAL SOLUTIONS.

The main obstacle to a quick solution of the power difficulty was the lack of legal authority to make direct advances of public funds to enlarge going power plants or to build new ones. As the several problems were studied and solutions presented and urged for action in the spring of 1918 by the power section, this was the final difficulty not surmounted in a comprehensive way. As stated above, it was met in a limited way by certain Army supply contracts which included the costs of necessary plant in the cost of manufacture and provided for the ultimate purchase of such plants by the contractors.

The most generally useful plan for affording Government aid was worked out by the power committee already referred to, consisting of Mr. R. J. Bulkley, Brig. Gen. Keller, and Mr. F. Darlington, the credit for which belongs mainly, however, to the first named. This plan was based on the fact that the only way of obtaining funds for additional power-generating facilities was from the great active governmental agencies, such as the War and the Navy Departments, the Shipping Board, etc., which already had appropriations available for work and supplies. The plan contemplated ascertaining which department was most involved or interested in the output of a particular district where shortage existed and with due regard to the relative demands of the departments, that the selected department contract for electric energy to be sold by it in turn to its contractors for supplies in such a way as to provide funds for the building and development of additional plants, parts of plants, and interconnections found necessary. This required an analysis of the business of the larger customers of the utility company or companies in a given section so as to determine what the products of the section were and to which departments they were being supplied. Three main sections were treated in this way—Pittsburgh, Philadelphia, and northern New Jersey. It was found that the Pittsburgh section required the most additional power and money, and the largest percentage of its product was taken by the Ordnance Department of the Army. Philadelphia required large additions, and it was found that the Shipping Board had the largest single interest there. The Navy, in turn, had a material interest in the output of northern New Jersey. Taking due regard of the relative amounts of assistance needed and of the requirements of these governmental agencies, it was decided to ask the War Department to aid at Pittsburgh, the Shipping Board at Philadelphia, and the Navy in northern New Jersey. This proposal was acceded to by the heads of these governmental agencies and ne-

gotiations were taken up with the parties concerned. The war ceased, however, before these arrangements were consummated, except in one or two instances, notably those for building a new power house by the West Penn Power Co. at Springdale, near Pittsburgh, Pa., and additions to power plants at Brunots Island and at Lorain, Ohio. The form of agreement used in this contract is important, as it embodies a method by which Government funds could be advanced for plant construction under an order given for electric energy to be delivered by a new plant when completed or by others under the same control. Under this plan the amount advanced by the Government was not to exceed 40 per cent of the actual cost of the plant, this being the estimated war risk, the utility company having to assume the remaining 60 per cent, and the contract provides for the payment of this loan while at the same time making provision also for protecting the power company against loss due to war conditions—that is, against the war risk—this being done by a readjustment of the unit price of energy in a manner fully described in the contract.

The amount advanced by the Government was really a loan. It was assumed, from general knowledge of the prices existing in 1918 as compared with those of 1914 and 1915, that 40 per cent was a conservative estimate of the excess cost of a power plant built in 1918 over what its cost would be when prices became normal, say, about five years after the war ended.

INSTALLATIONS BY SEVERAL DEPARTMENTS.

On similar lines, but not following the exact form, the Emergency Fleet Corporation and the Ordnance Department of the Army installed or assisted in the installation of a number of plants. At the time this report was compiled, the Emergency Fleet Corporation had installed 55,550 kilowatts in plants and substations at certain industries and shipyards. The Ordnance Department of the Army had aided in the installation of 100,000 kilowatts of generating apparatus and transmission lines for a maximum demand of 200,000 kilo-volt-amperes, besides aiding a large number of smaller projects, thereby furnishing additional facilities for its munitions program.

The Navy Department did very little in this line, except that it undertook to obtain power for the Public Service Electric Corporation in New Jersey by cable connection from the New York Edison Co., in New York. This arrangement was not, however, completed before the armistice.

The plan devised by the committee of the power section worked well, but it had a certain possibility of delay, and it was necessary to follow the lines of logical development of the companies concerned which had to raise 60 per cent of the cost. On account of the emergency, however, the extensions demanded by the best interests of the United States departed more and more from developments as planned by each company acting separately, and required more immediate though sometimes temporary relief by means of cooperation and interconnection between existing companies, involving large expenditures of money and many business, rate, and legal problems, as well as for facilities not ordinarily useful to these companies.

INSTALLATIONS BY UTILITY COMPANIES.

The utility companies themselves could not justly be expected to cope with this situation, particularly as to interconnections over long distances. While financial aid was necessary to a number of companies embarrassed by the circumstances of the industry, as detailed earlier in this report, on the other hand, during the preceding two years a large amount of machinery and plant, aggregating about \$200,000,000, had been installed by public utility companies from their own resources.

WAR FINANCE CORPORATION.

In a few cases the utility companies were able to take advantage of the method of financing offered by the creation of the War Finance Corporation. This corporation had the power to rediscount securities accepted by banks as surety for loans to utility corporations. It also could loan funds directly to utility corporations on satisfactory securities to the extent of 80 per cent of their full value. This source of relief was too limited to meet the necessities of the situation in most cases requiring aid, although advances to the amount of \$40,858,900 were made up to November 30, 1918.

THE FINAL PLAN OF RELIEF.

PROPOSED RELIEF.

In order to definitely remedy the power shortage after consultation with the other departments of the Government and interests concerned, and after final approval by the President of the course proposed, the War Industries Board, in August, 1918, requested Congressman T. W. Sims, chairman of the House Committee on Interstate and Foreign Commerce, to introduce a bill the object of which was to allow the President to provide means for the better utilization of existing sources of power and the development of new sources. It provided \$175,000,000 for the purchase and building of power plants. The bill was drawn on broad lines, authorizing the building of power plants, the increase in capacity of private plants or assistance in equipping or expanding such plants, the purchase of power plants, the leasing of plants or taking over of their product and its distribution, and the construction of pipe or transmission lines necessary for distribution or interconnection. Authority was further given to change, cancel, or suspend any existing and future contracts for power so that it might be distributed to the advantage of the production of war material. New corporations could be formed, private or public rights acquired, mergers or consolidations of private plants could be made, and property acquired could be duly sold, if desirable, under certain reasonable restrictions. This bill, known as H. R. 12776, would have solved the problem of obtaining additional power and would ultimately have made available means for relieving many localities where power was short.

The bill was supported in person before Congress by the Secretary of War, Chairman Baruch of the War Industries Board, and Director Garfield of the Fuel Administration; also by the Shipping Board, the War Finance Corporation, and others. Its passage was

urged by all familiar with the problem of sufficient power supply. It passed the House and in due course was submitted to a Senate committee for investigation, when the events leading up to the German defeat began and the consideration of the bill ceased with the signing of the armistice. It is proper to state here that the Senate committee had not approved the bill as presented to it and had one or two substitutes under consideration when the war ended. A copy of the bill is appended, marked "Exhibit C."

This method of conserving and increasing the power supply, obviously the only method easy and direct, as well as comprehensive, had been proposed early in the year, practically as soon as the general character of the power shortage became evident. At that time, however, and later on several occasions it was impossible to secure for it the necessary official support. Thus it was 16 months after our entrance into the war that a really comprehensive program met with official and legislative support, and even then action for its adoption was far from prompt. The remedy for this condition of affairs is discussed in another place.

ADMINISTRATION OF SHORTAGES IN 1918.

Slight additions only had, therefore, been made to the power plants where shortages were feared, and in due course they began to develop in the fall of 1918; first in Baltimore, due to low water flow in the Susquehanna River, from which water power was supplied to Baltimore; then in New Jersey, Philadelphia, and Pittsburgh, from breakdowns in machinery and overloads; and again in the South, particularly in Georgia, on account of drought and low water supply and consequent deficiency in hydroelectric power. To meet the difficulties it seemed advisable that power be assigned on a preferential basis, and in October a method for the preferential assignment of power was placed in effect by the War Industries Board.

The method of apportionment of power described below was put into effect about October 1 by the priorities committee in order to supply power in the proportions deemed most necessary to the various industries engaged in the manufacture of war products. Prior to this decision several other methods had been tried, which although effective in some instances, did not prove thoroughly satisfactory. The most common of these was one known as the rotation method. This method consisted in the following arrangement:

When a shortage of power existed in a given territory and the power for nonessential uses had been reduced to a minimum, the remaining customers were notified that thereafter on certain days in each week or certain hours in each day they would receive only a fraction of the power they required or no power at all. When this was confined to short intervals in a day, so short that it did not interfere with the work of the employees, this method met with fair success but it was not successful beyond this point. Further, this method was applied without discrimination as to the importance in the war program of the various industries. This was a vital point and was covered by the priorities committee in Circular No. 20, known as Preference List No. 2, issued at the beginning of September, 1918. In this preference list industries are arranged in four

classes, graded in importance from class 1 to class 4—class 1 being those industries and plants of exceptional importance in connection with the prosecution of the war, their importance being so high that their requirements must precede those of the three remaining classes in order that they might receive their full allowance of power at all times. Except in extreme cases, all small consumers having a connected load of 100 horsepower, or less, were included in class 1. The possible saving in electric energy through curtailment of such small consumers would not justify the losses and industrial disturbances that would follow.

Classes 2, 3, and 4 took preference in the order named and were given a relative weight, after class 1 had received full service, of 5, 3, and 2. The power requirements of each class were multiplied by these figures and the sum of these products divided into the power available gave a decimal fraction which multiplied by the weighted loads gave the amounts of power to be allotted to each class. Under this arrangement the power allotted to these classes would always fill a proportion of their demands in the ratio 5, 3, and 2. It is possible under this arrangement that when classes 2 or 3 had extremely small requirements in proportion to the total demand of the district they might receive an amount in excess of their respective needs. In such case this excess was to be distributed between the classes given incomplete service. If only one class were left incompletely served the overallotment of the other two was to be assigned to it. The service given to a specific industry depended therefore on its classification by the priorities committee—this classification having been determined from returns made by the company concerned. The rating of a company could be changed as between the various classes by a rerating of the priorities committee.

So far as it was used this apportionment of power proved satisfactory and inconvenienced the more important war industries to the smallest extent. It was applied in the shortages arising in the fall of 1918 in New Jersey, Baltimore, Philadelphia, and Pittsburgh.

A copy of Circular No. 45 of the War Industries Board covering this subject is appended,¹ marked "Exhibit D."

REVIEW AND CONCLUSIONS.

This brief résumé of the gradual realization of the importance of the supply of power to the war program and the various attempts to relieve the situation until its conditions were understood must be given to prove that its great value was finally appreciated and active measures taken to provide for it.

It is plainly shown in the tables of power requirements for each district, as estimated for the winters of 1918-19 and 1919-20, that the supply was insufficient for the prompt supply of materials of war for our first army of 2,000,000 men. The great necessities with which to make the scientific war of these times beyond the actual fighting soldier are raw material, labor manufacturing appliances, transportation facilities and power, with brains and money to combine them. All these we had in abundance, and we provided more or less successfully for their combination and control, with the ex-

¹ Not printed.

ception of power. This we neglected, for it was assumed we had it in quantity. Only the sudden end of the war prevented this from being shown by a serious shortage of power supply with which to meet the increased demands for the equipment of an army of 5,000,000 men.

Only the ending of the war prevented conclusive proof that we has made the same mistake as England, but to a smaller relative extent, namely, provided our factories and raw materials and placed orders for finished materials without sufficient power to manufacture them promptly.

It is necessary to establish these facts in their order to prove the point at which this report is directed. The supply of power should have been given primary attention at the beginning of the war, the same attention that was given to the methods and means of transportation, both on land and sea. Suggestions of the methods to be pursued in case of another emergency are given later in this report. Immediately following is given a very brief summary of the difficulties encountered in endeavoring to provide additional power in the most important industrial sections, which shows the necessity for taking immediately on the opening of another great war the course proposed in part 4.

PART 3.

BRIEF DESCRIPTION OF THE POWER SHORTAGES IN THE MOST IMPORTANT SECTIONS AND THE METHODS OF RELIEF.

A summary is given here of the power shortages existing and the methods taken to relieve them in the important districts of—

Niagara Falls and Buffalo,
Pittsburgh and eastern Ohio,
The New England States,
The State of New Jersey,
Philadelphia and eastern Pennsylvania,
Wilmington, Del., and Baltimore, Md.,
The Pacific coast,

where a full supply of power was most necessary. The detailed account of what was done in these and other locations mentioned is given at length later in this report.

THE NIAGARA FALLS-BUFFALO DISTRICT.

POWER SUPPLY.

The Niagara Falls-Buffalo district was one of the first to develop a demand for power in excess of possible supply, and the problem and procedure there will be briefly described. The industrial area so designated covers the northern and western portion of the State of New York from Buffalo to Syracuse and draws its supply of power from hydroelectric plants from the Salmon River on the east to the Niagara on the west, including many small powers between the two. This hydro power is supplemented by a number of steam plants, the largest being at Buffalo, Lyons, Rochester, and Syracuse. The principal companies furnishing power in the district are the Hydraulic Power Co. and the Niagara Falls Power Co. (now consolidated), the Buffalo General Electric Co., the Niagara, Lockport & Ontario Power Co., the Rochester Railway & Light Co., and the Syracuse Lighting Co., with other smaller generating and distributing companies which in many cases use power furnished by the larger companies mentioned.

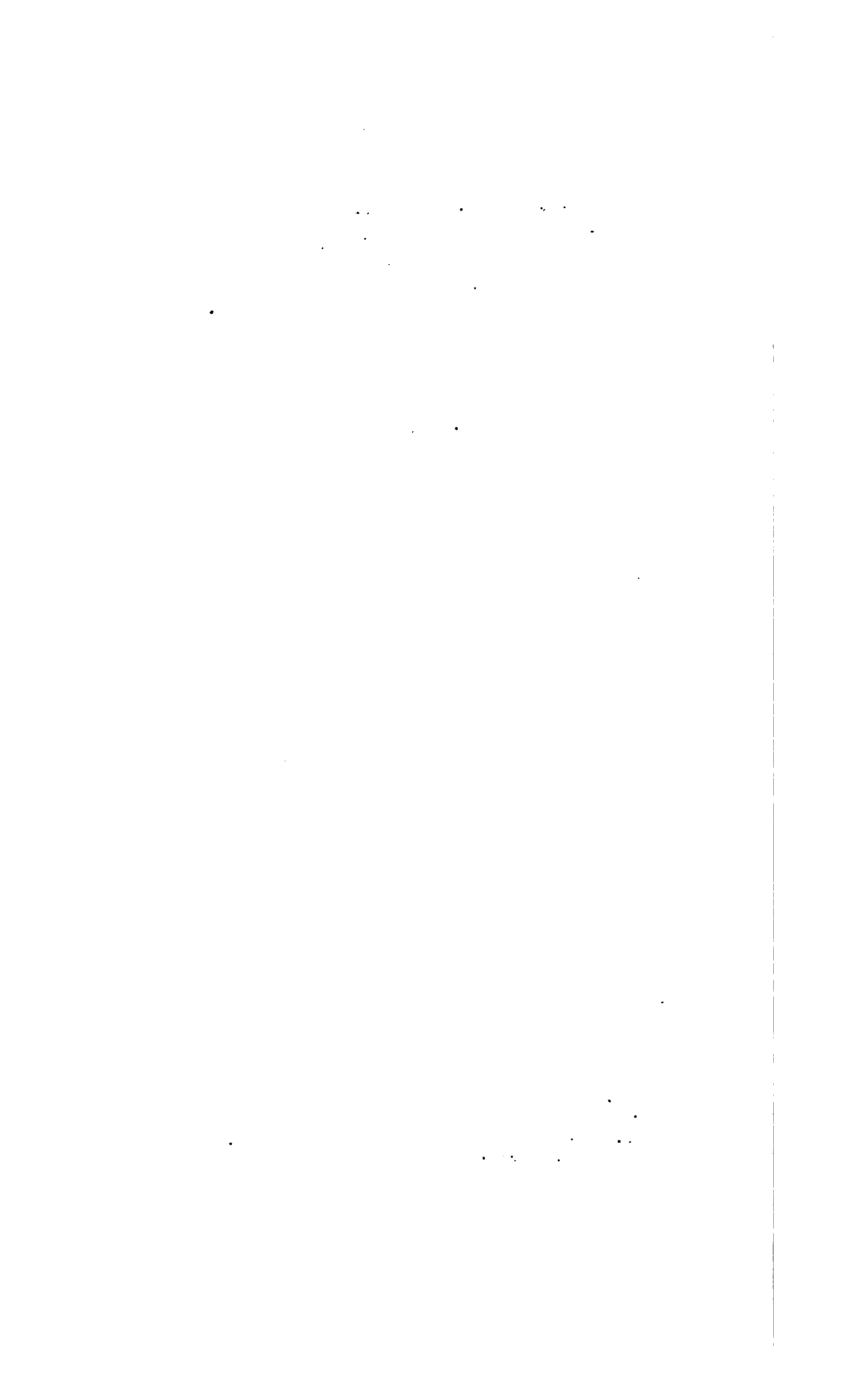
The principal industries in this district are very important in case of war and comprise the great chlorine, phosphorus, and other chemical plants at Niagara Falls, large ferroalloy, electrode, and carbide factories, aluminum works, and a number of electric steel furnaces.

POWER AVAILABLE.

Including all power resources, such as Canadian supply, steam stations, contributions from Rochester and Syracuse, there was an

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[illegible]



apparent available operating capacity of 483,600 horsepower, but until the middle of 1918 the highest total realized from the four larger companies in the district just mentioned was about 476,000 horsepower. Of this power about 91,000 horsepower was imported from Canada, about 275,500 produced by hydraulic power in the United States, and 117,100 produced by steam in this country.

The problem in this district was particularly one of producing continuous power. Except in Buffalo, a steady demand existed for all the 24-hour energy that could be produced. Additional water power by further diversions of water from the Niagara River was not obtainable in time to be of value in the war, for in addition to the time necessary for construction international agreements involving legal and political problems on both sides of the Niagara River would have taken too long to overcome.

ACTION TAKEN.

Three things could be done: First, by cooperation with the Canadians to maintain the present supply of hydraulic power from them, supply them with necessary fuel for their needs, arrange for mutual restriction of use of power to war necessities, and, in general, cooperate to accomplish this common object. Second, to increase the size of the steam plants and utilize all steam plants, whether efficient or not, to relieve the acute shortages recurring from time to time. Third, to increase the hydraulic power available by utilizing the water at higher efficiency to the limit of diversion allowed by treaty.

Mr. Bulkley and Gen. Keller, with the support of the Secretary of War, applied themselves energetically to this problem on these lines, and while they could not hope to secure sufficient power to supply the possible manufacturing capacity of the district, they made remarkable progress, more than was actually made in any other section. If the war had lasted another year a large amount of additional power—over 100,000 horsepower—would have been available.

Briefly, this was accomplished by the following means: The Canadian legal, political, and cooperative conditions were adjusted by Mr. Bulkley and Gen. Keller. Immediate steps were taken to restrict the use of electric power to essential war production throughout the whole region using power from any of the sources of supply mentioned. This involved restrictions in most of the cities and towns from Syracuse, N. Y., to Dunkirk, N. Y., and an additional supply of power was realized for war purposes of over 30,000 horsepower. A satisfactory feature of the program was that of requisitioning for the United States Government the entire output of the Hydraulic Power Co. and the Niagara Falls Power Co. This was done by a requisition of the President of the United States and resulted in taking control of the energy produced and apportioning it to the various chemical and other works in the district in the proportion indicated by preferences expressed by the priorities committee of the War Industries Board. It should be recorded that this course was adopted not because it was required to induce the companies to act for the best interests of the Government, but to relieve them of possible legal complications which might have interfered with their most efficient action during the emergency. This arrangement worked perfectly

and harmoniously and undoubtedly produced the best results possible. It further created a precedent which made it unnecessary to requisition the energy supply of other companies, either here or in other districts. As a matter of convenience it would have been preferable to extend this procedure, but it was not deemed expedient to do so. The detail of this part of the work is set forth in two reports to the Secretary of War, dated December 8, 1917, and May, 1918, by Gen. Keller and Mr. Bulkley.

STEAM ADDITIONS.

As immediate relief from additional water supply was out of the question, attention was given the steam supply and its possible increase. It was found that both the Niagara, Lockport & Ontario Power Co. and the Buffalo General Electric Co. were endeavoring to increase their steam plants, the first by 15,000 horsepower and the second by 26,000. Every effort was made to assist them in this work by obtaining preferential treatment for their machinery and supplies and their transportation. It was hoped that this 41,000 horsepower would be available early in the summer of 1918, but the best that could be realized was to get the 15,000-horsepower unit going during July at part load. On account of unexpected tests, delays, and troubles the generator of the Buffalo company was not started until after the war ceased. This was a good example of the shortage of steam turbine machinery and the delay in its delivery caused by the demands of the Navy, Emergency Fleet, and of other public agencies. Although ordered long before the war started and promised for delivery so that it was deemed certain it would be in operation in July, 1918, the Buffalo turbine had not been started on January 1, 1919.

It was found on investigation that certain additional supplies of power could be obtained by cutting off the supply of hydroelectric energy to certain smaller distributing companies throughout the State and making them start up their steam plants. This was not efficient from one standpoint but very effective from another. Quite material supplies of power in the aggregate were obtained, the greatest being obtained from the large plants of Syracuse and Rochester, which economized as far as possible in their use of hydro energy from the Niagara, Lockport & Ontario Power Co., ran their steam plants to full capacity as required, and supplied steam power to the Niagara system. Minor changes were also made to improve the transmission arrangements of the Niagara, Lockport & Ontario Power Co. so that it could carry power to its customers around Niagara from the east instead of conforming to its normal distribution of power derived from the west to the industries of the east. Strange as it may seem, it may be stated as a general fact that during the last year of the war no Niagara power was sent farther east than Lockport, the demand being so great around Niagara. Economies in the use of power in Buffalo were made by reducing the power allowed to industries nonessential to the war, the power so saved being used at Niagara.

Arrangements were in progress to do this on a larger scale at the time of the closing of the war.

The power difficulties of this district centered about the demands of the electrochemical companies, located at and near Niagara Falls and Buffalo, which employed electrical energy in comparatively large blocks. It was therefore most desirable to increase the hydroelectric output at Niagara so that while the power available was being redistributed and used to the utmost benefit an important hydraulic development was started and gotten well under way at Niagara Falls. This contemplated a large addition to the hydraulic power by more efficient utilization of the water already diverted. The relative efficiency of the two large water power companies, the Hydraulic Power Co. and the Niagara Falls Power Co. was in the proportion of over 19 to 11. In other words, a cubic foot of water used by the Hydraulic Power Co. was producing 19 horsepower while the Niagara Falls Power Co. was only producing 11 horsepower from the same flow.

From the mass of discussion and the numerous plans on the utilization of Niagara water power Gen. Keller and Mr. Bulkley selected, and the Secretary of War authorized, the execution of a plan which as the result of exhaustive studies had been judged to be that which would furnish at the earliest date a sensible addition to the power supply, while at the same time employing the water with high efficiency. Under this plan, when completed, all the water diverted from above Niagara Falls will produce about 20 horsepower per cubic foot of diversion, leaving the remainder of the fall of the Niagara River to be developed with corresponding efficiency whenever the market demand may justify and the law permit. While this plan had many advantages, it was selected mainly for two reasons: First, it did not interfere with any other plan proposed for the further and future utilization of Niagara on a larger scale, and, second, because it met the emergency of time to the best effect. In other words, it could be installed in a shorter time than any other plan proposed. The plan proposed the use of the water then diverted by the Niagara Falls Power Co. in an extension of the more efficient plant of the Hydraulic Power Co., and it further contemplated the grant to that company of authority to divert permanently the unassigned 4,400 second-feet still available under the terms of our treaty with Great Britain.

In order to accomplish this object, many obstacles had to be overcome. The rights of the two companies had to be consolidated, and the State of New York had to consent to the consolidation. A bill was introduced in Congress to authorize the issuance by the Secretary of War of a long-time permit for the utilization and diversion of 4,400 cubic feet per second of additional water. This was necessary in order to justify the heavy investment required for new plant, but the companies were able to finance themselves if the legal matters referred to were arranged. The physical work to be done consisted in enlarging the intake and canal of the Hydraulic Power Co. and building an extension of the power house of this company. In spite of the many difficulties involved and the fact that Congress has not yet confirmed the arrangement made for the increased hydraulic power provided, construction work was begun early in the summer of 1918, and 65,000 horsepower could have been obtained from this development by May 1, 1919. This was the largest and

quickest addition to the power resources of the country anywhere in the United States. For the details of this project reference is made to the House bill No. 11871, Sixty-fifth Congress, second session, and the hearings thereon. This bill was never enacted into a law, but was ultimately disposed of by incorporating its provisions so far as was necessary in the general power bill, which is still before Congress. The power companies were, however, given a revocable permit by the Secretary of War to use the additional amount of water required to develop a part of the increased power supply.

TABLES AND DIAGRAMS.

Three tables and one map are attached as exhibits showing the Niagara situation. Table A shows the capacities of the various power companies and the estimated shortage of the district. Table B shows the savings of power made and its reapportionment to the most important products. Table C shows the general distribution of power in the districts after elimination of nonessential uses. The map shows the general scope and distribution system of the Niagara, Lockport & Ontario Co. Copies of the requisitions for and waivers of the output of the two large hydraulic companies are also attached.

TABLE A.—Table of power available at present in Niagara Falls, Buffalo, and northern New York district. Additional power to be installed in summer of 1918 and actual shortage estimated in winter of 1918-19.

Companies.	Hydro power now (horse-power).	Steam power now (horse-power).	Steam power added this summer, new (horse-power).	Steam power obtainable from Rochester and Syracuse (horse-power).	Adjustments (horse-power).	Totals 1918-19 gross horse-power, available (horse-power).	Actual shortage estimated for 1918-19 (horse-power).	1918-19 latent shortage (horse-power.)
Niagara Falls Power Co.....	140,000				$\left. \begin{array}{l} -37,500 \\ +10,000 \end{array} \right\}$	112,500		¹ 60,000
Hydraulic Power Co. Niagara, Lockport & Ontario Power Co..	144,000				$\left. \begin{array}{l} -27,500 \end{array} \right\}$	144,000		¹ 53,300
Buffalo General Electric Co.....	69,000	26,500	15,000	10,600	$\left. \begin{array}{l} +37,500 \\ -10,000 \end{array} \right\}$	121,100	² 13,300	
	13,500	80,000	³ 46,500		$\left. \begin{array}{l} +27,500 \end{array} \right\}$	107,500	10,000	
Total.....	366,500	106,500	61,500	10,600	27,500	⁴ 545,100	⁴ 23,300	113,300 23,300 ⁴ 136,600

¹ Electro-chemical companies could use these amounts in 6 months if obtainable, but would require additional cable and apparatus.

² Shortage depends on supply from Canada, Rochester, and Syracuse. Can be restricted by cutting off commercial industries.

³ Rated generator capacity. Restricted to 26,000 horsepower additional at present, due to lack of boiler capacity.

⁴ Line losses, repairs, spare machines not deducted.

⁵ Shortage due to firm power released to Niagara Falls Power Co. ⁶ Total actual and latent shortage.

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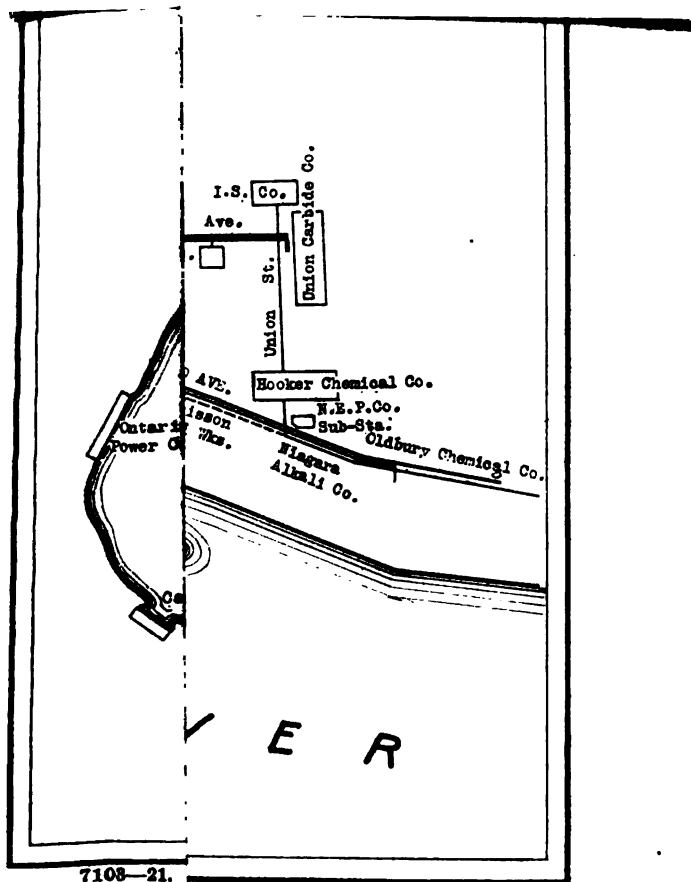
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TABLE B.—Niagara Falls-Buffalo district—Increased allotments of power to essential electrochemical industries in April, 1918, as compared with power used in November, 1917, under normal conditions.

Product.	Ferrosilicon.		Electrodes.		Abrasives.		Phosphorus, etc., sodium cyanide.		Chlorine, etc.	
	Nov., 1917.	Apr., 1918.	Nov., 1917.	Apr., 1918.	Nov., 1917.	Apr., 1918.	Nov., 1917.	Apr., 1918.	Nov., 1917.	Apr., 1918.
Union Carbide Co.....	H. P. 66,867	H. P. 178,964	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
Defiance Paper Co.....	0	2,034								
International Paper Co.....	0	3,000								
U. S. Alloys Co.....	6,720	9,176								
	73,587	93,174								
Increase.....		19,587								
National Carbon Co.....			2,577	4,761						
International Acheson Graphite Co.....			5,408	7,908						
Star Electrode Works.....			4,083	5,683						
			12,068	18,352						
Increase.....				6,284						
Carborundum Co.....				10,483	12,700					
Increase.....					2,217					
Oldbury Electrochemical Co.....							5,654	8,654		
Increase.....								3,000		
Niagara Electrochemical Co.....							9,506	13,506		
Increase.....								4,000		
Mathieson.....									10,343	11,750
Iscro Chemical Co.....									1,300	1,900
Niagara Alkali Co.....									7,077	7,377
Niagara Smelting Co.....									1,125	1,319
									19,845	22,346
Increase.....										2,501
Total increase.....										37,589

¹ Hydraulic Power Co.; Niagara Falls Power Co.; Niagara, Lockport & Ontario Power Co.

² Used by Union Carbide Co. until April, when paper companies began ferrosilicon manufacture.

³ Hydraulic Power Co.

⁴ Niagara Falls Power Co.

⁵ Buffalo General Electric Co.

⁶ Power supplied by Niagara, Lockport & Ontario Power Co.

TABLE C.—Niagara Falls-Buffalo district—Table showing in detail the use of electric energy as produced during a typical period in the winter of 1917-18.

[Percentage of total output.]

	Niagara Falls Power Co.	Hydraulic Power Co.	Niagara, Lockport & Ontario Power Co., Niagara & Erie Power Co.	Buffalo General Electric Co.
Direct war industries.....	73.53	97.05	58.31	50.27
Transportation purposes.....	11.55		21.21	21.47
Street, commercial, and residence lighting; water supply.....	7.81	1.96	7.61	13.99
Commercial power consumers, over 100 horsepower.....	1.62	.13	5.94	2.82
Small commercial power.....	3.61	.78	6.80	7.49
Nonessential purposes.....	1.98	.09	.13	3.96
	100.00	100.00	100.00	100.00

TEMPORARY WAIVER OF DELIVERY OF HYDRAULIC, MECHANICAL, AND ELECTRICAL POWER BY HYDRAULIC POWER CO., OF NIAGARA FALLS, AND CLIFF ELECTRICAL DISTRIBUTING CO.

Whereas the President of the United States, by virtue of and pursuant to the authority vested in him, and by reason of the exigencies of the national security and defense, has placed an order with Hydraulic Power Co., of Niagara Falls, and Cliff Electrical Distributing Co., on the 28th day of December, 1917, and on the same date has requisitioned from them the total quantity and output of hydraulic, mechanical, and electrical power which is capable of being produced and/or delivered by said companies, or either of them, through the use of all waters diverted or capable of being diverted through the hydraulic canal of said Hydraulic Power Co. and/or the plants and machinery of said companies connected therewith; and

Whereas said Hydraulic Power Co., of Niagara Falls, and said Cliff Electrical Distributing Co., and each of them, have requested to be permitted to carry on their business of production, sale, and distribution of such power as is or may be developed or generated by them, respectively, in whatever manner and to whatever extent may be deemed to be consistent with the exigencies of the national security and defense; and

Whereas in the judgment of the Secretary of War such exigencies will be provided for adequately for the time being if the hydraulic, mechanical, and/or electrical power capable of being produced and/or delivered by said companies, respectively, be sold by and for the account of said companies and distributed by them in the manner shown in the attached schedule; and

Whereas said companies, and each of them, have offered to waive all claim for compensation from the United States by reason of said order and requisition and/or the delivery of power under the conditions set forth in the schedule hereto attached, save as to such power as actually may be delivered to the United States;

Now, therefore, the Secretary of War, acting for and in behalf of the United States, hereby, until further notice to said companies, waives delivery to the United States of any of the power capable of being produced and/or delivered by said companies, on the express condition that said companies shall distribute such power as provided in the schedule hereto attached.

Upon request of the Secretary of War, or his duly authorized representative, said companies, and each of them, shall furnish a sworn statement showing the users of said power during any specified period, together with the maximum quantity of power delivered daily and the rate of compensation charged to each user, and such other information as may be requested.

Said Hydraulic Power Co. of Niagara Falls and said Cliff Electrical Distributing Co., and each of them, hereby waive any and all right to compensation from the United States by reason of said requisition and order, and/or delivery of said power under the conditions hereinbefore imposed.

In witness whereof this instrument has been executed in triplicate on the 28th day of December, 1917, on behalf of the United States by the Secretary of War, and the said companies have caused the same to be executed and their corporate seals attached by their presidents thereunto duly authorized.

Secretary of War.

HYDRAULIC POWER CO. OF NIAGARA FALLS,

By -----,

President.

CLIFF ELECTRICAL DISTRIBUTING CO.,

By -----,

President.

SCHEDULE.

The Hydraulic Power Co. of Niagara Falls and the Cliff Electrical Distributing Co., and/or each of them, shall deliver all power, delivery of which is waived by the United States as provided in the attached waiver, under existing con-

tracts, to the persons now entitled to receive such power, with the following exceptions:

1. The delivery of power developed by Hydraulic Power Co. of Niagara Falls through its penstocks, water wheels, and appliances, to which are attached electrical generators owned and operated by the Aluminum Co. of America, shall be reduced by so much hydraulic power as may be necessary for the development of four thousand (4,000) m. h. p. (whenever and to such extent as said hydraulic power is needed to supply Cliff Electrical Distributing Co. with mechanical power in order to furnish electrical power as required by this schedule), which power shall be delivered by Hydraulic Power Co. of Niagara Falls to Cliff Electrical Distributing Co. for the generation of electrical power.

2. Six thousand (6,000) m. h. p. which is now being delivered by Hydraulic Power Co. of Niagara Falls to Cliff Electrical Distributing Co. for delivery in the form of electrical power to the Aluminum Co. of America, in accordance with the terms of a tripartite contract made by Hydraulic Power Co. of Niagara Falls, Aluminum Co. of America, and Cliff Electrical Distributing Co., dated the 26th day of November, 1912.

3. The delivery of electrical power to the following consumers shall be curtailed as herein indicated:

Cataract Ice Co. and Niagara Falls Ice & Storage Co.—The total delivery to these two companies shall not exceed 250 horsepower.

Cliff Paper Co.—No power after January 2, 1918.

Defiance Paper Co.—No power after January 2, 1918.

Frontier Brick Works.—No power.

Said Cliff Electrical Distributing Co. shall use the additional power deliverable to it from Hydraulic Power Co. of Niagara Falls, pursuant to this schedule, and the power made available by the curtailments herein prescribed or otherwise, to increase the amount of electrical power deliverable to the users named below, it being the intent hereof that they shall receive, respectively and continuously, the approximate amounts of electrical power set opposite to their respective names:

	E. H. P.
Electro Metallurgical Co.-----	41, 000
National Carbon Co.-----	6, 000
Oldbury Electro Chemical Co.-----	6, 000
Hooker Electro Chemical Co.-----	10, 000
Niagara Alkali Co.-----	6, 000
Isco Chemical Co.-----	1, 400

The foregoing table is based upon the ability of said Hydraulic Power Co. of Niagara Falls and said Cliff Electrical Distributing Co. to operate their plants and lines at full capacity and efficiency.

Whenever said Cliff Electrical Distributing Co. shall have a surplus of electrical power above the requirements of its customers under the provisions of the attached waiver and this schedule it shall make distribution thereof to the customers on its lines in the following order of priority, viz:

National Carbon Co.
 Oldbury Electro Chemical Co.
 Electro Metallurgical Co.
 Hooker Electro Chemical Co.
 Niagara Alkali Co.
 Isco Chemical Co. (Inc.).
 National Electrolytic Co.
 U. S. Light & Heat Corporation.
 General Abrasive Co. (Inc.).
 Titanium Alloy Manufacturing Co.
 Aluminum Co. of America.

In case of a deficiency of the supply of said mechanical and/or electrical power said Hydraulic Power Co. of Niagara Falls and said Cliff Electrical Distributing Co. shall withdraw such power first from consumers not named above, and then from the several named customers in the inverse order of the foregoing list so far as the same may be done without undue damage to the plants and/or products of said several customers. There shall, however, be no curtailment of power deliverable to public utilities or to small users employing an average of not to exceed one hundred (100) horsepower each until after all larger users shall have been curtailed so far as such curtailment may be effected without causing undue damage.

TEMPORARY WAIVER OF DELIVERY OF ELECTRICAL POWER OF NIAGARA FALLS POWER CO.

Whereas the President of the United States, by virtue of and pursuant to the authority vested in him and by reason of the exigencies of the national security and defense, has placed an order with Niagara Falls Power Co. on the 28th day of December, 1917, and on the same date has requisitioned from it the total quantity and output of electrical power which is capable of being produced and/or delivered by said company through the use of all waters diverted or capable of being diverted through the intake canal of said Niagara Falls Power Co. and/or the plants or machinery of said company connected; and

Whereas said Niagara Falls Power Co. has requested that it be permitted to carry on its business of production, importation, sale, and distribution of such power as is or may be developed, generated, or imported by it in whatever manner and to whatever extent may be deemed to be consistent with the exigencies of the national security and defense; and

Whereas in the judgment of the Secretary of War such exigencies will be provided for adequately for the time being if the electrical power hereby ordered and requisitioned from such company be sold by and for the account of said Niagara Falls Power Co., and distributed by it in the manner shown in the attached schedule; and

Whereas said company has offered to waive all claim for compensation from the United States by reason of said order and requisition and/or the delivery of power under the conditions set forth in the schedule hereto attached, save as to such power as actually may be delivered to the United States.

Now, therefore, the Secretary of War, acting for and in behalf of the United States, hereby, until further notice to said company, waives delivery to the United States of any of the power capable of being produced and/or delivered by said company, on the express condition that said company shall distribute such power as provided in the schedule hereto attached.

Upon request of the Secretary of War, or his duly authorized representative, said Niagara Falls Power Co. shall furnish a sworn statement showing the users of said power during any specified period, together with the maximum quantity of power delivered daily and the rate of compensation charged to each user, and such other information as may be requested.

Said Niagara Falls Power Co. hereby waives any and all right to compensation from the United States by reason of said requisition and order and/or delivery of said power under the conditions hereinbefore imposed.

In witness whereof this instrument has been executed in duplicate on the 28th day of December, 1917, on behalf of the United States by the Secretary of War and the said company has caused the same to be executed and its corporate seal attached by its president hereunto duly authorized.

SCHEDULE.

The Niagara Falls Power Co. shall deliver all power delivery of which is waived by the United States as provided in the waiver attached under existing contracts to the persons now entitled to receive such power, except that delivery of electrical power to the following consumers shall be curtailed as herein indicated:

Hooker Electro Chemical Co.—Reduced to 5,100 horsepower.

Niagara River Manufacturing Co.—No power between hours of 6 a. m. and 7.30 p. m.

Said Niagara Falls Power Co. shall use the additional power made available by increased use of water in its canal or by the curtailments herein prescribed or otherwise to increase the amount of electrical power deliverable to the users named below—it being the intent hereof that they shall receive respectively and continuously the approximate amounts of electrical power set opposite their respective names:

	Horsepower.
Carborundum Co.-----	13,500
Acheson Graphite Co.-----	7,000
Niagara Electro Chemical Co.-----	13,500

The foregoing table is based upon the ability of said Niagara Falls Power Co. to operate its plants and lines at full capacity and efficiency.

Whenever said Niagara Falls Power Co. shall have a surplus of electrical power above the requirements of its customers under the provisions of the fore-

THE POWER SITUATION DURING THE WAR.

giving waiver and this schedule it shall make distribution thereof to the customers on its lines in the following order or priority, viz:

Star Electrode Works.
Acheson Graphite Co.
Union Carbide Co.
Oldbury Chemical Co.
Niagara Electro Chemical Co.
Carborundum Co.
Phosphorus Compound Co.
Mathieson Alkali Works (Inc.).
Hooker Electro Chemical Co.
Niagara Alkali Co.
Norton Co. of New York.
Aluminum Co. of America.
Buffalo General Electric Co.

In case of a deficiency in the supply of electrical power said Niagara Falls Power Co. shall withdraw power first from consumers not named above and then from the several named customers in the inverse order of the foregoing list, so far as the same may be done without undue damage to the plants and/or products of said several customers. There shall, however, be no curtailment of power deliverable to public utilities or to small users employing an average of not to exceed 100 horsepower each until after all large users shall have been curtailed, so far as such curtailment may be effected without causing undue damage.

THE PITTSBURGH AND EASTERN OHIO DISTRICT.

The power situation at Pittsburgh was among the first to draw attention to the supply of power and its apportionment. Due to the multiplicity of orders pouring in on the manufacturers of this district, they in turn demanded power, and, not getting it to the extent desired promptly, appealed for aid to the Government departments that had ordered materials from them. These in turn proceeded to order the utility companies to supply power for the particular product they wanted most at the time and these governmental requisitions were made without knowledge of or regard for the power situation as a whole. The ensuing difficulties caused the Duquesne Light Co., of Pittsburgh, to appeal to the priorities committee of the War Industries Board in the fall of 1917 for guidance, and Mr. Bulkley was asked to proceed there to adjust the apportionment. This he did in a broad way, which took care of the situation until the following fall, when a close classification of industries in order of preference had been made and an Engineer officer assigned to administer the power supply. Gen. Keller became associated with Mr. Bulkley in the Pittsburgh situation, and they handled the power affairs during the winter of 1917-18 together.

GENERAL SITUATION.

Soon thereafter the power section was organized, and among its first surveys was that of this district, including the manufacturing cities of Pittsburgh, Connellsville, Wheeling, East Liverpool, Steubenville, Canton, Massillon, Alliance, Akron, Warren, and Youngstown, and their contiguous areas in Pennsylvania and Ohio. Of these cities those in Allegheny County and the Youngstown district alone produced in 1916 over 36 per cent of the output of pig iron, steel ingots and castings, and rolled steel of the United States. The Pittsburgh district also produced about 40,000,000 tons of bituminous coal in the same year. This coal production was about 30 per cent

low on account of labor and transportation difficulties. These figures establish the great importance of the war production of this district, and in view of the reported shortage of power a thorough investigation of the power requirements of the district, their supply, and administration was urgently demanded.

This was promptly taken up after Mr. Bulkley's first visit there in December, 1917. At this visit he found that a shortage existed, caused in a way by defective administration and breakdowns of machinery. The Duquesne Light Co. was supplying customers in rotation on assigned days, and the West Penn Power Co. was at the same time importuning it for additional power on account of failure of some of its equipment. The rotation program of the Duquesne Co. was changed to a preferential arrangement, a reduction of power to nonessential industries was ordered, and the public appealed to for economy. At the same time an adjustment was made between the West Penn and the Duquesne Cos. so as to relieve, to the greatest practicable extent, the difficulties under which each was laboring. With the support and cooperation of both companies, these changes proved effective and were continued permanently.

DEMAND ON DISTRICT.

Survey and study of the district were begun by the power section in January, 1918, and quickly developed the fact that the war orders pouring into the district had created a demand for power much in excess of the possible supply; that this demand would increase rapidly as the war progressed and a larger army created for which arms and equipment must be furnished; that on account of the business and financial conditions discussed earlier in the main report the companies had no active program for increasing their output, and, beyond a few scattered items, no additions to the power supply of the district were in progress. The plants of the district were already strained by the load put upon them, and certain generators had broken down and needed repair, with the certainty that others would follow.

SPECIAL PLANT CONDITIONS.

Only one exception can be made to these statements. A large power plant of the so-called superpower type was in course of construction at Windsor, on the Ohio River, about 12 miles above Wheeling, W. Va. This plant, after some accidents and delays, had just gotten one 30,000-kilowatt turbogenerator into operation and was furnishing energy to the territory southwest and south of Pittsburgh, along the Ohio River from Wheeling to East Liverpool, and as far west as Canton, Ohio. An additional 30,000-kilowatt generator was in place and awaited the completion of the necessary boiler plant to go into service. This plant was operated as the Central Power Co. One half of it, as it stood, was owned by the American Gas & Electric Co. and the other half by the West Penn Power Co., a company operating in the belt of small towns immediately surrounding Pittsburgh, particularly to the southwest, south, and east of that city. The West Penn Co.'s principal power plant was at Connellsville, southeast of Pittsburgh, and was in poor condition; one of its larger machines there was out of service and others were

operating uneconomically on account of breakdowns and auxiliaries. Its main power business was in coal mining, and the serious condition of the Connellsville plant aggravated the whole power situation because of the effect upon the coal output. The West Penn Co. had a contract with the Duquesne Light Co. for power at less cost than the cost of producing and transmitting this energy from Windsor and probably from Connellsville. This arrangement continued until the overloaded condition of the Duquesne Co. compelled its modification, obliging the West Penn Power Co. to draw on its Windsor plant, which furnished power to it up to 20,000 kilowatts on some days. The Windsor plant was also furnishing power to the plants of its other joint owner, the American Gas & Electric Co., at Canton, Wheeling, Steubenville, and East Liverpool. The plants at Canton and Wheeling were important and were unable to meet the demands upon them, but by forcing their local resources were able to decrease their demands on Windsor so as to help the West Penn Co. and Duquesne Co.

PROPOSED PLAN FOR INCREASE.

Early in 1918 a careful study was made of the entire district and a plan was devised by Maj. Lacombe for the interconnection of the plants of the district and the installation of additional machinery largely along the lines of the logical development of the various companies interested. This plan, carefully arranged as to the respective shares therein of each company, was designed to provide for the greatest relief in the shortest time. Early in July it was submitted to the various companies at a meeting of their representatives in Washington, but it was found they could do little or nothing on account of the impossibility of financing any construction whatever. This plan is shown by the diagram inserted at page 12, which shows the capacity installed in 1917, that to be added in 1918 and 1919, and the interconnecting transmission lines.

The generating capacity proposed to be installed in 1918 as shown was 100,000 kilowatts, while it was known that at least 130,000 kilowatts would be required to give a reasonable reserve. It was not, however, possible under existing circumstances to obtain and install the machines for 130,000 kilowatts in 1918 even if the work could be financed immediately; therefore, risks due to possible overload were contemplated under war conditions which would not be otherwise good practice. In order to produce power needed in 1919 it would be necessary to start work on its development early in 1918. The 230,000 kilowatts recommended for 1919 was based on the assumption that the load would increase in 1919 as much as it had been estimated to increase in 1918, and that certain machinery running in 1918 must be shut down in 1919 on account of its age, bad condition, or the excessive amount of coal consumed. The assumed load increase in 1919 was probably too conservative, since the war production of the district had been very much hindered by lack of power and would have increased more rapidly had a supply of power been in sight. For several months the Secretaries of War and of the Navy had prohibited the placing of orders requiring power for their production in the Pittsburgh district.

Maj. Lacombe's plan was based fundamentally on the relief of Pittsburgh by connection with Windsor, part of the necessary line from Washington to Windsor being already in existence, and the installation at Windsor of two more 30,000-kilowatt generators. This would have made a great bus connection with an interchange capacity of 40,000 to 60,000 kilowatts between the 100,000-kilowatt plant at Brunots Island in Pittsburgh, and the 60,000-kilowatt, later to be 120,000-kilowatt, plant at Windsor. The further addition of a 15,000-kilowatt generator at Youngstown, as planned by the Youngstown Company, with a short transmission line connecting with Pittsburgh would have been of great value and a further source of strength in the greater Pittsburgh district. If these two projects could have been taken up by the Government early in 1918, a heavy shortage in Pittsburgh proper and in the main part of the district could have been avoided in the winter of 1918-19, and the war output materially increased. Beyond a few items of additional plant equipment, it developed, however, that the utilities could do nothing further even with a certain amount of Government assistance, except in one instance, in which the West Penn Power Co. agreed to build a power plant of 40,000-kilowatt capacity at a point called Springdale, on the Allegheny River about 12 miles northeast of Pittsburgh, close to a coal mine and ample water facilities.

GOVERNMENT ASSISTANCE.

The Government, through the War Department, agreed to advance 40 per cent of the cost under a contract that provided that the war excess cost, depreciation, etc., were to be adjusted by appraisal of the duplication value of the plant three years after the close of the war. This plant would have helped the Pittsburgh situation in 1920, possibly late in 1919, but would have had no effect on the war shortage of 1918 and 1919. It would also have relieved the Duquesne Light Co. of the necessity of supplying energy under the previously mentioned contract with the West Penn Power Co. in its territory northeast of Pittsburgh. Just before the closing of the war it was planned to have the West Penn Power Co. put in another 30,000-kilowatt generator at Windsor and build the necessary transmission line into Pittsburgh, and so supply an emergency connection to the Duquesne Light Co. for the relief of Pittsburgh. The example of the West Penn Power Co.'s success in financing part of its work, with Government assistance on the balance, had its effect on others, and the Duquesne Light Co. made an attempt to finance and build a plant at Cheswick, also northeast of Pittsburgh, planned by it before the war. Here it had its own coal mine, and the condensing-water facilities provided by the Allegheny were ample. The plant proposed was to be ultimately 300,000 kilowatts, and the immediate project was for 120,000 kilowatts, at a cost of about \$15,000,000. This was to be financed on the same plan as the West Penn Power Co., but before the contract could be placed the war was so near its end that the project was abandoned by the Government for the reason it could not be completed until 1920, and therefore would perform no war service.

SPECIAL REMARKS.

As affairs stood at the close of the war it would have been two years after the war started before any material increase in power resources had been made in the immediate Pittsburgh district. It is a strange commentary on the foresight of the power companies of this district where a great and growing demand for power always existed, that even with the impetus given to this demand by the war, early in 1917 a 60,000-kilowatt machine ordered for one of the companies was diverted to Government uses for a nitrate plant, because the company's bankers could not or would not finance its installation. The power from this machine, which might have been ready in 1918, would have been absorbed at once by the market awaiting it. As a matter of fact, now that the war is over, this amount of power and more could be absorbed in this district, in which no great effort had been made to develop the full uses of electric power. The underlying reasons for this condition and the delay in remedying it are the financial and other difficulties of the power industry from 1914 to 1918, and the fact that during the war there was no simple way under which the Government could provide power facilities readily for its own war necessities. It has been noted that in the Niagara district the companies could finance themselves, needing Government assistance in overcoming legal obstacles only. In the Pittsburgh district at large this was not true, and financial aid was necessary. This was the case even with the American Gas & Electric Co. at Windsor, which, with the West Penn Power Co., had financed the first two 30,000-kilowatt units at that plant. The third unit, installed about January 1, 1919, was financed with the aid of the Goodrich Rubber Co. at Akron, Ohio, which needed additional power at Akron and had arranged to get it from Windsor in connection with the Northern Ohio Traction Co. at Akron by means of a transmission line from Canton to Akron, extending the Canton-Windsor transmission line.

REPAIR PROGRAM.

While these larger plans were being considered, such emergency measures and assistance as could be provided were being applied. In April, 1918, a program of repairs to meet the requirements of the West Penn Power Co. and the Duquesne Light Co. was worked out and put in effect. Every possible aid was given the American Gas & Electric Co. to finish and extend its power plant at Windsor by means of increased priority orders for material and railroad facilities. Similar efforts were made to help the other companies in the district, notably at Canton and Massillon, but little actual gain was made in power. The Windsor plant did get its second generator going early in the summer of 1918, and additional transformer capacity was added to the West Penn Power Co.'s distribution system at Washington, in the heart of one of its important districts, south of Pittsburgh. A new boiler was added at Connellsville in 1918, and additional ones arranged for with the Duquesne Light Co. to be installed early in 1919. A power transmission line was built by request of the Government from Canton to Massillon, but was not completed at the end of the war. It would have served to partially

relieve the very overloaded plant at Massillon by furnishing power through Canton from Windsor. A line was also started from Canton to Akron by the Northern Ohio Traction Co., to supply power from Windsor to the large rubber manufacturers at that point. A 10,000-kilowatt generator had been put in at Canton in 1917, a 2,500-kilowatt generator was installed at Alliance early in 1918, and a 10,000-kilowatt machine was put in at Warren, but all of these machines were loaded as soon as they were put in service. The 10,000-kilowatt generator at Canton broke down in 1918 and was not fully restored to service at the end of the war. All of the generators of the West Penn Power Co. at Connellsville were not repaired by the fall of 1918, so that it was short from 6,000 to 15,000 kilowatts; the largest generator of the Duquesne Light Co., 45,000 kilowatts, was out of service for two months in the summer of 1918; on account of defects in the design of the generators at Windsor, the manufacturers had cut their allowable capacity to 22,000 kilowatts each, so that the district was in a very bad condition.

SHORTAGE.

When the load began to come on in the fall of 1918, a shortage occurred which was administered in accordance with the preference schedule of the priorities committee of the War Industries Board already described. Power supply to nonessentials was very much reduced and power was limited so far as practicable to the manufacture of war essentials until November 11, shortly after which date Government control of the situation was given up.

TABLES AND DIAGRAMS.

Tables are given showing the capacity of generators in the district early in 1917, the additions planned, loads estimated, for 1918-19, and a diagram map (see p. 12) of the proposed scheme for the supply of sufficient power to the district had the war continued.

TABLE A.

	Available installed generating capacity.	Maximum load winter of 1917-18.	Prospective increase by winter of 1918-19.
	<i>Kilowatts.</i>	<i>Kilowatts.</i>	<i>Kilowatts.</i>
Alliance.....	2,500	2,500	7,100
Akron.....	35,000	35,000	23,000
Canton.....	31,000	26,000	12,000
Duquesne.....	129,660	128,600	46,400
Massillon.....	8,200	7,800	10,000
Warren.....	13,250	6,600	9,400
West Penn.....	166,240	62,378	32,622
Wheeling.....	13,500	14,760	8,000
Youngstown.....	43,000	30,800	24,200
Total.....	342,340	314,428	173,722

¹ 15,000 kilowatts of the capacity of No. 1 unit of the Windsor station is assigned to Canton and the remaining 15,000 kilowatts to West Penn.

The available installed capacities of the generating stations are based upon the outputs that might be reached under the most favorable conditions without any reserve units.

TABLE B.

Company.	Aggregate of available generating capacity now installed, and in process of building and not waiting for financial aid.	Estimated maximum loads up to Jan. 1, 1919.	Surplus.	Deficiency.
	<i>Kilowatts.</i>	<i>Kilowatts.</i>	<i>Kilowatts.</i>	<i>Kilowatts.</i>
Alliance.....	16,000	9,800		3,800
Akron.....	50,000	58,000		8,000
Canton.....	38,000	38,000		
Duquesne.....	129,650	175,000		45,350
Masillon.....	8,200	17,800		9,600
Warren.....	16,000	16,000		
West Penn.....	84,000	95,000		11,000
Wheeling.....	21,500	22,750		1,250
Youngstown.....	58,000	55,000	3,000	
Total generating capacity.....	411,350	487,150	8,000	73,800
		411,350		3,000
Deficiency in capacity.....		75,800		75,800

¹ Capacity of station now limited to 2,500 kilowatts by the cooling tower. The installation of a 2,500 kilowatt unit and sufficient boiler and cooling tower capacity for this unit and an increase in the output of the present units to 3,500 kilowatts is to be made.

² 7,000 kilowatts of the capacity of No. 2 unit at Windsor are assigned to Canton, 8,000 kilowatts to Wheeling, and 15,000 kilowatts to West Penn, this being in addition to 15,000 kilowatts of No. 1 unit to West Penn and 15,000 kilowatts to Canton. West Penn by repairs this summer will bring the reliable capacity of their plants aside from Windsor up to 54,000 kilowatts.

THE NEW ENGLAND STATES.

CAUSES OF SHORTAGE.

The problem of power supply in New England, particularly in the winter of 1917-18, differed from that at Niagara and Pittsburgh. It was largely due to a shortage in fuel caused by neglect to prepare for war demand by extra storage in the summer and fall and accentuated by a very severe winter, preceded by a drought which had depleted the streams and the storage reservoirs of the hydroelectric power plants. The usual supply of coal to New England by sea was decreased by the activities of the Navy and the Fleet Corporation, which had requisitioned most of the ocean-going tugs, barges, and large equipment. Due to the very severe winter, railroad operation became difficult, particularly on account of the excessive movement of freight for Europe to the tidewater ports, causing congestion there and at the railway portals to New England, Albany, Poughkeepsie Bridge, and Hoboken. This made it very difficult to get coal through and the situation became desperate not only as to fuel for power but also as to coal for domestic purposes. Fuelless days were introduced by the Fuel Administration, practically shutting down industrial production and shipments, thereby giving a chance to clear the gateways and slowly dissolve the congestion of traffic.

In the late fall of 1917 shortage of power was reported at Claremont, N. H., and at Worcester, Mass. It was found that at Claremont more power was required on account of war orders. This could be supplied by interconnection with contiguous companies, but the

business negotiations for it were somewhat difficult. This was disposed of satisfactorily. At Worcester a similar shortage had occurred, due primarily to a shortage of coal and partly to insufficient boiler capacity to operate the turbogenerators at full load. For a short time part of the customers shut off their load during the peak hours, from 4 to 7 p. m., and this successfully met the emergency. In 1918 the company installed additional boilers and put itself in a position to go through the winter of 1918-19 without difficulty as well as to furnish further power if called for.

SURVEY OF DISTRICT.

A comprehensive survey of the New England district was made by Maj. Sever in March, 1918, and it was found that local power shortages were to be anticipated at Claremont, N. H., as described above, at Pittsfield, Mass., Waterbury, Conn., and Portland and Lewiston, in Maine. The Pittsfield shortage would be due, if it occurred, to inability to secure boilers and turbogenerators in time, these being delayed by prior Government demands. Waterbury, Conn., was developing an extensive water-power plant at Stevenson, which would give an ample supply of power if completed, as was probable, by the late fall of 1918. Portland and Lewiston, Me., were both unable to finance additions to their stations and could not take on the additional load required. They remained in this condition throughout the war.

SHORTAGE FOUND.

Maj. Sever also found a shortage would exist in the power supply of the New England Power Co. This was most serious, more so than any of the isolated cases mentioned. This system extends from Vermont and the northwestern corner of Massachusetts into Rhode Island to Providence, besides lines through to Norwich and eastern Connecticut. It obtains power from a number of hydraulic plants, in northwestern Massachusetts, New Hampshire, and Vermont, and from several steam stations in Massachusetts, and Rhode Island, particularly from the large station of the Narragansett Lighting Co. at Providence. The power so obtained is distributed along its lines all over the territory mentioned and this company is the largest single factor in the power supply of the New England States.

The manufacturing interests of New England taken individually are small, perhaps, when compared with individual plants in the Niagara or Pittsburgh districts. The factories are many, however, and densely cover the States of Massachusetts, Connecticut, and Rhode Island, so that the aggregate demand is heavy. The production of New England was principally in wool and cotton goods, boots and shoes, ammunition, rifles, guns, gun carriages, and wire. It was essential, therefore, that the New England Power Co. should be able to supply the additional demands of many customers scattered over a wide area.

ACTION TAKEN.

Immediate steps were taken to obtain all possible supplies of power. These finally resolved into four sources of supply which might be completed by the late fall. They were, first, a connection from Boston through Dedham to Clinton to supply a maximum of

20,000 kilowatts from the Edison Illuminating Co. of Boston, which in turn was being aided to obtain additional generating capacity, promptly, by preferences given by the priorities committee. Second, the Narragansett Lighting Co. was urged to put in additional boilers to increase its capacity and enable it to increase delivery to the New England Power Co. A line connecting Providence and Fall River was also put through, gaining strength in power resources for both places. Third, the New England Power Co. began erecting a 10,000-kilowatt turbogenerator at its Uxbridge steam plant and fourth, a new steam plant was started at Thamesville, Conn., near New London, under the name of the Eastern Connecticut Power Co., for a capacity of 20,000 kilowatts. While all these projects were aided by the Government so far as possible by priorities, etc., it is probable that none of them could have furnished any power until late in the winter of 1918-19, perhaps in February or March. An exception to this was the additional boiler capacity at Providence. A further resource developed in an existing interconnection of the New England Power Co., with the Turners Falls Power & Electric Co., through which a new station of the United Electric Light Co. at Springfield became available for surplus power. Energy was also secured from the Worcester Electric Light Co. at Worcester.

HYDROELECTRIC MATTERS.

These are all steam sources. No new water-power plants could be made available in time to be of any aid in the winter of 1918-19, although arrangements were made for some additional hydro supply which could probably be in service in 1919. These arrangements consisted in promoting agreements between the parties interested aided by the incentive of the national war necessity and by the efforts of the power section, who discussed and presented the matter from an unbiased point of view, which invariably enabled fair agreements to be reached. Thus additional water power at Bomoseen Lake was arranged for the Rutland system and at Bellows Falls for the New England Power Co.

In western Connecticut there was no power shortage, except as noted at Waterbury, and the difficulties encountered were due to insufficient fuel supply. The additional hydroelectric plant of the Connecticut Light & Power Co. at Stevenson would have relieved the situation in 1919 at Waterbury and New Britain and, by interconnection, at Hartford and Middletown.

In southeastern Massachusetts a rather uneconomic situation existed among a number of smaller communities. Two systems extended from Quincy, just south of Boston, to New Bedford, which were not interconnected. With a view to fuel saving and more economical operation, a committee of engineers worked out a system for the interconnection and cooperation of the various plants and certain of these operating arrangements were put into effect during the war, but the main plan of interconnection was not fully adopted nor construction begun before the end of the war.

MAINE.

In Maine three different systems or power companies were in operation. The Cumberland County Power & Light Co. served Port-

land and Biddeford, along the coast to York Harbor, and inland to Sanford. Primary power is derived from water power from the Presumpscot and Saco Rivers to the north of the communities just mentioned, emergency steam plants providing for contingencies of load and hydrosupply. The Androscoggin Electric Co. supplies power from hydrostations at Lewiston to that town and vicinity and as far south along the interurban railroad as West Falmouth, but does not interconnect with the Cumberland Co. at Portland. The Androscoggin Co.'s lines for interurban railway purposes also extend southeasterly to Freeport, Brunswick, and Bath, along the coast, but again do not interconnect with the Central Maine Power Co. at Brunswick or Bath. The Central Maine Power Co. furnishes power over the territory which may be described as south central Maine, its lines extending along the Kennebec River and its tributary, the Sebasticook, from Bingham and Moosehead Lake to Waterville, Augusta, Bath, and Brunswick, as well as running east to Rockland, Belfast, and Brookville. This company supplies power from 11 hydrostations and 5 steam stations to a large number of factories in the communities along its lines. It has sufficient power, provided its steam plants are supplied with fuel, although dependence is mainly placed on hydropower. No detailed study was made of this system, but it is understood it had a number of undeveloped water powers available for future needs.

During the period of the war the only power shortage in Maine was on the system of the Cumberland County Power & Light Co., serving Portland. Here the power requirements were increased by a demand by the United States Railroad Administration for 2,000 horsepower for unloading and reloading wheat brought in through Canada to relieve the Atlantic ports farther south. This was decreased to an actual demand of 500 horsepower for the winter of 1918-19, with the further 1,500 to come in the next year. This smaller demand was met by temporary means. A larger plan to obtain power for this company through the Androscoggin Co., from the surplus power of the Central Maine Co., could not be successfully worked out at the time, but undoubtedly would have been before the larger supply for 1919 was necessary.

From a glance at the map it is obvious that the three companies should be interconnected and should cooperate to utilize to the utmost their hydroelectric resources, save fuel, and cheapen production.

UTILIZATION OF WATER POWER.

On account of the high cost of fuel the utilization of available water powers in New England was most important, but none could be developed in time to be of service. Several water powers on the Westfield River near the Turners Falls Power & Electric Co.'s system, others on the Deerfield River near the New England Power Co.'s system, and a general development improving the water powers along the Connecticut River were all suitable for immediate action, but could not have been completed within one or two years. The cost of development was very high at this time, and the difficulty of financing practically insuperable. In consequence, every effort was directed toward increasing the steam resources of the district.

The greatest source of cheap power for New England lies in the water powers in western Maine and eastern New Hampshire, where a large block of power can be collected and transmitted to the distributing systems of Massachusetts. Many difficulties must be overcome which would require a great deal of time and trouble, but this possibility is briefly described with some summary figures in the section of this report entitled "Power and Production."

Reference is made to a diagram showing the main systems and their interconnections throughout New England, and also a table, made by Maj. Damon, showing the results that would have been accomplished by the proposed additions to the steam resources of the New England Power Co. and interconnected companies.

APPENDIX A-1.

New England—Interconnected system summary.

Place or company.	Maximum load, 1917.	Estimated increase, 1918.	Estimated increased maximum load, 1918.	General capacity, 1917.	General increase, 1918.	Estimated total general capacity, 1918.	Estimated total surplus or shortage.
	<i>Kilowatt.</i>	<i>Kilowatt.</i>	<i>Kilowatt.</i>	<i>Kilowatt.</i>	<i>Kilowatt.</i>	<i>Kilowatt.</i>	<i>Kilowatt.</i>
New England Power Co. ¹	62,000	31,000	93,000	.....	.....	.....	.....
New England Power Co., hydroplants, 10 hours ¹.....	.....	.....	.....	27,000	.....	27,000	.....
Wachusett Reservoir, 10 hours ¹.....	.....	.....	.....	2,000	.....	2,000	.....
Uxbridge steam plant. ¹.....	.....	.....	.....	5,000	(10,000)	5,000	.....
Narragansett Electric Lighting Co. ¹.....	.....	.....	.....	20,000	8,000	28,000	.....
Worcester Electric Light Co. ¹.....	.....	.....	.....	5,000	.....	5,000	.....
Shore Line Electric Railway Co. ¹.....	.....	.....	.....	.....	10,000	10,000	.....
Edison Electric Illuminating Co., Boston ¹.....	.....	.....	.....	.....	16,000	16,000	.....
Miscellaneous ¹.....	.....	.....	.....	2,000	.....	2,000	.....
Total .....	.....	.....	.....	61,000	34,000	95,000	2,000
Turners Falls Power & Electric Co.	26,000	16,600	42,600	.....	.....	.....	.....
1 hour peak capacity.....	.....	.....	.....	26,000	25,000	51,000	² 8,400
Normal 10 hour production.....	(17,000)	(13,000)	(29,000)	(17,000)	(25,000)	(42,000)	(13,000)
Worcester Electric Light Co.	17,000	2,500	19,500	25,000	.....	25,000	+5,500
Secondary power for New England Power Co. ....	.....	.....	.....	(5,000)	.....	(5,000)	.....
Narragansett Electric Lighting Co. ⁴	31,000	6,000	37,000	(33,000)	(17,000)	(50,000)	.....
Primary power to New England Power Co.	(2,000)	(11,000)	(13,000)	(2,000)	(11,000)	(13,000)	.....
Capacity for Narragansett Electric Lighting Co. ....	.....	.....	.....	31,000	6,000	37,000	.....

¹ Figures are on a basis of 10 hour production because the steam plants have ample capacity for all the night load and the hydroplants can carry the 1-hour peak. The maximum load of 1917 was more than the capacity because the capacity was figured on a normal low water flow, but the season was better than normal and the reservoir was drawn excessively and some power drawn from the Turners Falls Power & Electric Co. The 1-hour peak was 66,300 kilowatts.

² The Uxbridge addition probably can not be made this year. Boston connection will carry 20,000 kilowatts maximum.

³ Of the 8,400 kilowatt surplus above, about 6,500 kilowatts is in steam plants of lower efficiency than the new Hampden Station and will be shut down if possible.

⁴ The New England Power Co. has contracted for, and expects to use over the time of lowest water and the time of maximum load, all of the generating capacity of the Narragansett Electric Lighting Co. not needed by themselves. The primary power reserved for the New England Power Co. is given above, and the 10-hour equivalent production is included in the New England Power Co. analysis at the head of this table.

APPENDIX A-1—Continued.

New England—Interconnected system summary—Continued.

Place or company.	Maximum load, 1917.	Estimated increase, 1918.	Estimated increased maximum load, 1918.	General capacity, 1917.	General increase, 1918.	Estimated total general capacity, 1918.	Estimated total surplus or shortage.
	<i>Kilowatt.</i>	<i>Kilowatt.</i>	<i>Kilowatt.</i>	<i>Kilowatt.</i>	<i>Kilowatt.</i>	<i>Kilowatt.</i>	<i>Kilowatt.</i>
Blackstone Valley General & Electric Co.	(21,200)	(5,000)	(26,200)	(21,200)	(5,000)	(26,200)	.....
Generated by Blackstone Valley General & Electric Co.	15,700	.....	15,700	15,700	.....	15,700	.....
From New England Power Co.	(5,500)	(5,000)	(10,500)	(5,500)	(5,000)	(10,500)	.....
Fall River Electric Lighting Co. ^a	9,750	2,400	12,150	10,000	2,000	12,000	—150
Shore Line Electric Railway Co. ^a	3,900	4,800	8,500	8,200	(11,800)	(20,000)	(11,500)
Reserved for New England Power Co. ....	.....	(10,000)	(10,000)	.....	(10,000)	(10,000)	.....
Capacity for Shore Line Electric Railway Co. ....	.....	.....	.....	.....	1,800	10,000	1,500
New London, Conn. ^b	1,830	520	2,350	2,295	.....	2,295	—55
Springfield, Mass. ^c	15,000	2,500	17,500	15,000	11,000	26,000	8,500
	182,180	66,120	248,300	194,195	79,800	273,995	25,695
Boston, Mass. ^d	79,000	29,000	108,000	105,000	(30,000)	(185,000)	.....
Primary power to New England Power Co. ....	.....	(16,000)	(16,000)	.....	(16,000)	(16,000)	.....
Capacity for Boston. ....	.....	.....	.....	.....	14,000	119,000	11,000

^a The Fall River Electric Lighting Co. is building a 20,000 kilowatt line connection to the Narragansett Electric Lighting Co. for interchange of power.

^b The Shore Line Electric Railway Co. are building a new 20,000 kilowatt steam station but expect to shut down the old stations, which gave 8,200 kilowatts, because they are very inefficient.

^c The New London division of the Connecticut Power Co. will connect to the new plant of the Shore Line Electric Railway Co., this supplying the shortage.

^d The United Electric Light Co., of Springfield, is connected to the Turners Falls Power & Electric Co. for the interchange of 20,000 kilowatts.

^e The Edison Electric Illuminating Co., of Boston, has more generating capacity than shown above, but it is of lower efficiency and will not be operated except in extreme emergency. The Boston figures are not included in the total above because the connection to the rest of the system is of such limited capacity that the surplus in Boston can not be available. The new 30,000-kilowatt unit being installed will not be able to put out full load till after the heaviest load season of the winter has passed. Therefore, the 11,000-kilowatt surplus of efficient capacity will be reduced.

Figures in parentheses should not be added as they are included in figures of other companies.

THE STATE OF NEW JERSEY.

IMPORTANCE OF DISTRICT.

This State was the center of great activity during the war. Jersey City and Hoboken on New York Harbor became great points of transfer for troops and supplies as they are the termini of a number of the greatest railroads in the country as well as portals for freight for New England. These cities, with Newark, Bayonne, Paterson, Passaic, and others, clustered near the port of New York, were large manufacturing centers and the demands on them were greatly increased by war. A number of great ammunition plants and depots were created near these shipping points. There were increased activities in all the manufacturing cities in the interior of the State and in the important shipbuilding plants near New York Harbor and

near Camden. This activity called for increased and continuous power supply, which in this case was not forthcoming.

POWER SUPPLY.

The main resource for general power supply was the Public Service Electric Corporation of New Jersey, which operated two power systems in the State, one furnishing power to the dense manufacturing and shipping centers of the northern part of the State along and contiguous to the Hudson River and New York Harbor and also to the central portion as far south as Metuchen and vicinity. Eleven generating plants supplied these sections. The corporation also furnished power from four generating plants to the southern section from Trenton to Camden, Burlington, and Gloucester. The two sections were not interconnected, and under the circumstances little benefit would have resulted if they had been.

SHORTAGE.

There was a marked and persistent shortage of power throughout the State from the fall of 1917 throughout the winter and again in the fall of 1918. This was the result of shortage of coal and of generating capacity aggravated by a distribution system too limited to carry additional supplies of power without heavy losses and impaired regulation.

FUEL SUPPLY.

The coal supply began to run short of the daily requirements early in November, 1917, and so continued until March, 1918. The utility company had provided about three months' storage and perhaps relying on the assurances of the Fuel Administration did not make the extra effort required to keep this unimpaired. However, neither the Fuel Administration nor the utility company foresaw the greatly increased demand for power and the unusual difficulties of fuel supply during the extraordinarily severe winter of 1917-18. The Railroad Administration had hardly had time to get a strong hold on its work, and the Fuel Administration was certainly new to its problems, when an exceptionally severe winter closed down on the country early and enormously increased the difficulties of shipping, transporting, and distributing coal and freight of all sorts. Water transportation was practically stopped by ice and by shortage of coastwise shipping. In spite of all efforts coal could not be supplied to meet the requirements of the district, and several occasions arose during the winter when the supply of power was cut off for days at a time. The Fuel Administration gave as the reason for the acute situation that it was caused by the unprecedented weather preventing the railroads from furnishing cars and locomotives to coal mines supplying New Jersey points. In consequence it estimated only about one-fourth of the normal production was shipped from the mines. Whether this was admitted by the railroads is not known, although there was some dispute as to the responsibility for the general coal shortage which existed here and in New York City and State as well as throughout New England. One pertinent fact remains, namely, that the other power plants on New York Harbor, whether from

greater foresight or more adequate facilities, got through the winter without any serious interruptions to service, except in the case of the Interborough Railway Co., operating street railways in New York City. This company, however, does not provide itself with very large fuel storage capacity, but relies on daily supplies by barge; and even so, it had but a single shutdown of merely a few hours duration.

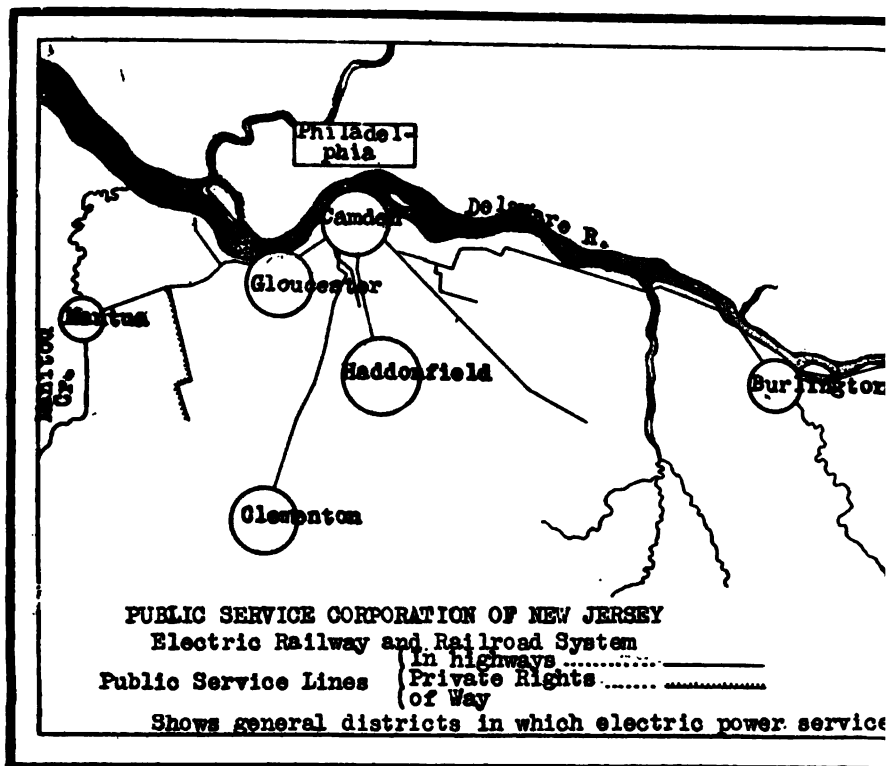
GENERATING CAPACITY.

The second cause of the lack of power supply was insufficient generating capacity. Careful studies and surveys of the power plants and the service required from them were initiated by Mr. Darlington in January and February, 1918, and continued throughout the year by the power section. It was found that the full demand could not be accurately ascertained for the reason that on account of known shortage and interruptions of service it never had the opportunity to develop. As closely as could be ascertained the actual requirements were much in excess of the plant capacity of the company. The maximum actual load developed for the system in both sections, at the time of the first examinations, was about 180,000 kilowatts. It was estimated that had power been available the load would have been at least 200,000 kilowatts in the winter of 1917-18. The reason for this conclusion is that, in spite of the fuel shortage, a number of private plants were kept in operation on account of impossibility of obtaining service from the utility company, and that later orders involving the use of additional power were not allowed to be placed in this territory.

The main problem in the New Jersey shortage was the 60-cycle system of the northern section. The southern section was taken care of by preventing additions to the load and by aid, when required, from certain private plants. The 25-cycle and direct-current systems of the northern section were sufficient for the demands on them. The demand on the 60-cycle system in the north was much above its actual operating capacity, which proved to be about 112,000 kilowatts. In consequence, with the aggravation of insufficient fuel supply to force such capacity as was available, the system could not carry its load, shutdowns of several days occurred, and severe restrictions of power supply were necessarily imposed.

ADDITIONAL GENERATORS.

Insufficient capacity had been foreseen and the company was in 1917 installing a 31,500-kilowatt turbogenerator at its Essex station on the Passaic River and a 11,200-kilowatt machine at Perth Amboy, and had laid out an extensive program of increased capacity for 1918-19, involving another 31,500-kilowatt generator at Essex and two 12,500-kilowatt at Burlington, as well as a 50,000-kilowatt generator in 1920, with additional boilers for the present machinery as well as additions and very necessary improvements to the distributing system. Of this program the 31,500-kilowatt generator at Essex and the 12,500 at Perth Amboy were installed, but the rest of the plan was abandoned on account of inability to finance it. Of the two generators installed, the large machine was not put in operation until the fall of 1918. The reason given was that on account of accidents to other machines of the same manufacture the utility





company would not take the responsibility of operation, although the manufacturer was willing to warrant the machine if run at somewhat less than its rated capacity until certain changes were made.

FINAL ANALYSIS AND RELIEF PROPOSED.

It appeared early in 1918 that a heavy shortage would occur in the winter of that year and that the company would not meet it. This shortage on the critical 60-cycle system was estimated at about 20,000 to 24,000 kilowatts, making a total load to be met of about 160,000 kilowatts with an actual capacity, including the two new units, of 142,000 kilowatts, reduced by the amount at which the 31,500-kilowatt generator was run below its rated capacity. With this condition known, various efforts were made to provide additional power. It was hoped for a while that Government funds would be available through the War Finance Corporation, but this hope proved illusory. Suggestion of a supply of power from the Hauto plant of the Lehigh Navigation & Electric Co. and the Philadelphia system by transmission from power plants at coal mines in eastern Pennsylvania and the interconnection of the three systems proved on careful investigation unwarranted because of the time required and the fact that Philadelphia had no steady power to spare. For the same reasons the suggestions of a relay generator plant for both Philadelphia and New Jersey situated at a point convenient for both systems proved futile. In March and April, 1918, Mr. P. H. Thomas, consulting engineer of the power section, proposed an interconnection to the Interborough Railway Co. of New York, which it was known had a large excess of capacity. As the shortage in New Jersey was on its 60-cycle power system and the Interborough was a 25-cycle system, this would have required frequency changers not at that time available. Another similar plan, based on an offer of the New York Edison Co., was presented early in June by Maj. Lacombe. This involved the operation of certain machinery of the New York company at the frequency of the New Jersey system, 60 cycles instead of the 62½ cycles peculiar to the New York Edison system. In consequence, the machinery necessary had to be disconnected from its home system and connected by cable to the New Jersey system to operate in parallel with it. Difficulties of financing arose on account of the temporary character of the demand. The New Jersey company would not in any way meet this expense, and there were no Government funds directly available for such use. Finally the New York Edison Co., through its president, offered to put in the necessary cables and apparatus to deliver the energy at the western portal of the Pennsylvania Railroad Tunnel, and it was suggested that the Navy Department take up the matter in line with the precedent of the control of the War Department in Pittsburgh with the West Penn Power Co.

This solution, after approval by the Pennsylvania Railroad, was finally adopted by the power section, was submitted to the Secretary of the Navy in a communication by Commander Staniford dated October 1, 1918, and approved by the Secretary. Negotiations were immediately begun with the New York Edison Co. and the Public Service Electric Co. The negotiations with the New York company proposed a contract with the Navy Department, under which the

company was to install the cables, etc., at its own expense. The contract provided for the amortization of the excess war cost over the recovery value of its appliances, the whole contract following the lines of the agreement between the War Department and the West Penn Power Co. already described.

A careful analysis in June of the shortage anticipated for 1918-19 and again corrected in the fall confirmed the estimate that at least 24,000 kilowatts would be needed to carry the peak of the load, but as the time was too short to install the connection to meet the extreme load the contract was drawn for 20,000 kilowatts, an installation of machinery in the year 1919 in New Jersey being anticipated to meet the demands of the winter of 1919-20. The only other changes in the original plan were to carry the cables from the Waterside station of the New York Edison Co., in New York City, to a connection with the Pennsylvania Railroad Co.'s tubes at Thirty-fourth Street and First Avenue and thence under the city, Hudson River, and Palisades, through the tubes to the western portal of the tunnel. From this point the energy was to be conducted to the Essex station of the New Jersey company and distributed, certain Government aid being allowed for this purpose.

Before the contract was closed the armistice was signed and the project abandoned. It may be stated, however, that just before this time another shortage of power occurred, due to boiler and generator trouble on the Jersey company's system, showing that the necessity of immediate relief was most urgent.

A diagram is attached showing the proposed connection with the plant of the New York Edison Co. in New York City. The general system of the Public Service Electric Corporation is also shown by diagram.

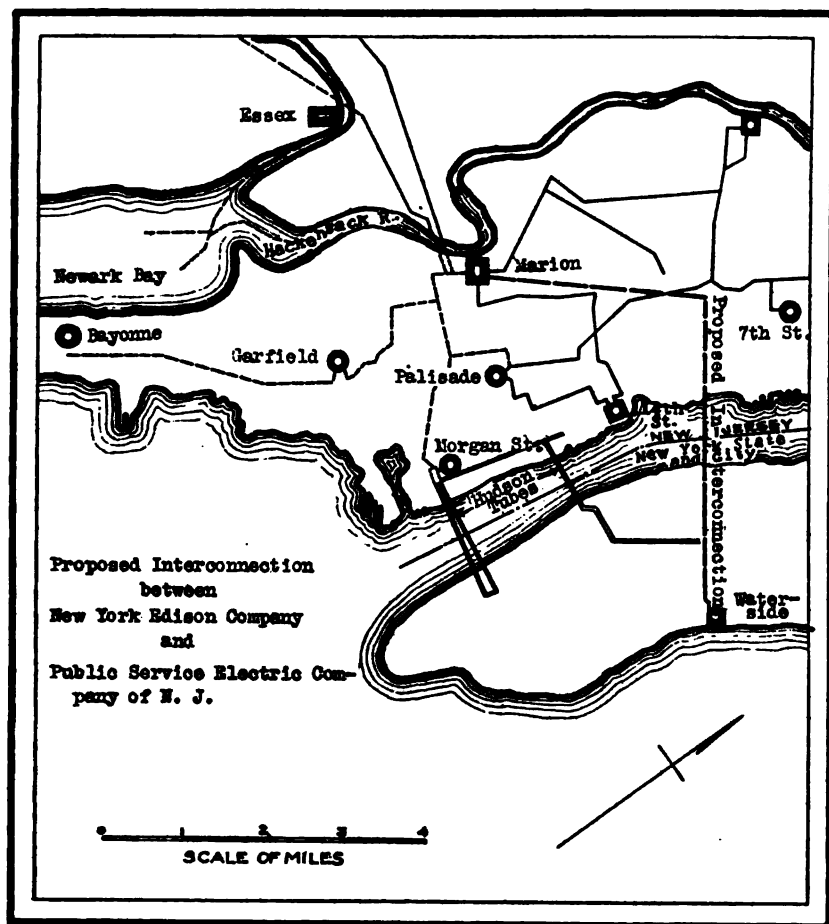
PHILADELPHIA AND EASTERN PENNSYLVANIA.

GENERAL SITUATION.

The general problem of power supply in this district was a serious one on account of the importance of the industries affected, particularly those of shipbuilding and munitions. The great Hog Island Shipyard of the Emergency Fleet Corporation is located at Philadelphia and required a large amount of power both for the construction of ships and the transportation of workers, besides creating a heavy direct demand on other industries of the vicinity. In addition, large munition plants were at or near Philadelphia, one of the largest of which, the plant at Eddystone, had been completed before the United States had declared war.

Philadelphia presents a fair example of the condition of the power industry described at the beginning of this report. The Philadelphia Electric Co. had realized the growing importance of power service in central-station work and had laid out a plan of development long before there was any thought of war. The preliminary financial, legal, and political arrangements had been worked out and two large power stations were put under construction, one known as the Delaware plant, to supply the demands of the northern portion, and the other, the Chester plant, to supply the southern portion of its territory. The two plants were ultimately, of course, to be interconnected to serve the entire community, if necessary, using older plants

as relays. The Delaware plant was not very far advanced, but the Chester plant fairly along. In spite of the financial strength of the Philadelphia Electric Co., on account of the difficulty of raising funds in 1917, the construction of the Delaware plant was discontinued in December and that of the Chester plant was materially delayed. While the delay at Chester was partially caused by late deliveries and labor shortages, time was also lost by efforts to obtain financial aid from the Government at reasonable rates in the hope of



preventing the exhaustion of the company's resources on the Chester plant alone. Such efforts were futile, however, and the company completed only the Chester plant. The Chester plant relieved the southern section of Philadelphia only, as the distribution system was not so developed as to transmit energy in any quantity across the city to the northern section.

STUDY OF DISTRICT.

On account of the grave importance of the Philadelphia district to the industries of the war special attention was given to a thor-

ough analysis of the district, its power needs, and all the possible sources of additional power. Philadelphia is at the heart of a great industrial district; it is closely related to New Jersey, immediately north; to the northwest lies Bethlehem and the great anthracite region of Pennsylvania, to the southwest Wilmington and Baltimore. Certain rather distant undeveloped water-power resources existed on both the Susquehanna and Delaware Rivers, and an important power system utilizing the cheap small sizes of coal and coal recovered from culm piles was in operation northwest of Philadelphia, at Allentown and Hazleton, which furnished power to the great steel plant at Bethlehem. Feeders from this company reached nearly to Philadelphia. Similar lines existed reaching toward the New Jersey Co. into Camden and lines of the utility company at Wilmington reached Chester. Unfortunately all these companies were also pressed for power. In examining the suggestions for additional power for Philadelphia, it was often found that through these new sources power might also be obtained for other companies.

SOURCES OF POWER.

It was suggested that power be brought to Philadelphia by a transmission line from power plants belonging to the Lehigh Navigation & Electric Co., enlarged and improved at Hauto and Harwood, the transmission line coming through Bethlehem, and also relieving the situation there. Another line from these plants was suggested going straight to Newark, N. J., with an interconnection to be built from Newark to Camden via Trenton, reaching to the Delaware plant of the Philadelphia Electric Co., and so combining the resources of the three systems.

A supplementary possibility was the transmission of water power generated on the Delaware River. Two propositions of this sort were suggested—one consisting of the development of four smaller powers above Port Jervis, on the Delaware, assembled at that point and transmitted by two transmission lines, one to Newark, N. J., and one via Bethlehem, Pa., to Philadelphia—with the idea particularly that this power would serve to relieve the peak load of the steam plants at these points. It was estimated that about 300,000,000 kilowatt-hours, at 40 per cent load factor, could be developed and transmitted. A much larger and more valuable plant was suggested, utilizing the water power of the Delaware River, mainly below Port Jervis, by a succession of reservoirs and power plants extending from near Hancock, N. Y., to Belvidere, N. J. By means of the extensive storage proposed no steam reserve plant would be necessary, and an output of about 300,000 horsepower on a 50 per cent load factor could be obtained. These two projects provided for peak power only, but this would have been an important gain. Based on prices before the war, it was estimated that the plant could be developed at a price less than \$100 per horsepower—the total cost aggregating about \$29,000,000.

Another source of water power exists to the south—Conowingo, on the Susquehanna River, about 12 miles below Holtwood, the present hydroelectric plant supplying Baltimore and Lancaster. This plant would develop about 600,000,000 kilowatt-hours in an average year, which could be transmitted 46 miles to the Chester

center of the Philadelphia system and also be available for Wilmington, if necessary.

By an interchange arrangement reconciling frequency differences, Baltimore being 25 cycles and Chester 60 cycles, a connection between Conowingo and Holtwood would tie these two hydropowers to the steam power of the Philadelphia plant. A connection could also be made from the Delaware plant of the Philadelphia company to the New Jersey system, reinforced in its turn by hydropower from the Delaware River, and to lines from the steam plants at Hauto and Harwood, in the coal-mining district. A further connection between the New Jersey plants near Jersey City and plants in New York City could be made and a great combination of resources and superpower plants be secured for the economic operation of a very great industrial section.

CONDITIONS FOUND.

But neither the New Jersey system, the Lehigh Navigation system, Wilmington, nor Philadelphia had any surplus power. Each system was very short, and doing its best against many difficulties to supply its own demand. The water-power projects referred to would furnish mainly peak power, but neither could be completed for service before 1920. The feasibility of a large power plant on the Lehigh Navigation Co.'s system, situated at a point where it could obtain an ample and continued supply of the small and cheap sizes of anthracite or a supply of this coal recovered from culm piles or in the form of silt was carefully investigated. It was found that the supply of such cheap fuel for a prolonged period was in considerable doubt. The building of such a plant would have required from 14 to 16 months, so that no immediate aid could be looked for from this prospect.

ACTION RECOMMENDED.

The quickest solution, then, reverted to the original plan of the Philadelphia Electric Co., namely, the completion of the Chester plant and the financing and completion of the Delaware plant at the northern end of the city, the addition of another 30,000-kilowatt unit at Chester as recommended by Mr. Darlington, chief of the power section, and, further, the building of the necessary interconnection and main distribution lines and substations. The matter of providing financial assistance for the completion of this work was then assigned to the Shipping Board and Emergency Fleet Corporation. The reason for this was that their interest in the district's output was preponderant and, following the line of policy adopted, it was held that they should finance the requirements of this district.

DELAY.

Although the recommendations of the power section had been supported and amplified by an independent report to Admiral Bowles, United States Navy, of the Emergency Fleet Corporation, by Dr. C. T. Hutchinson, of New York, the Shipping Board had a further investigation made, and from this an unfortunate dis-

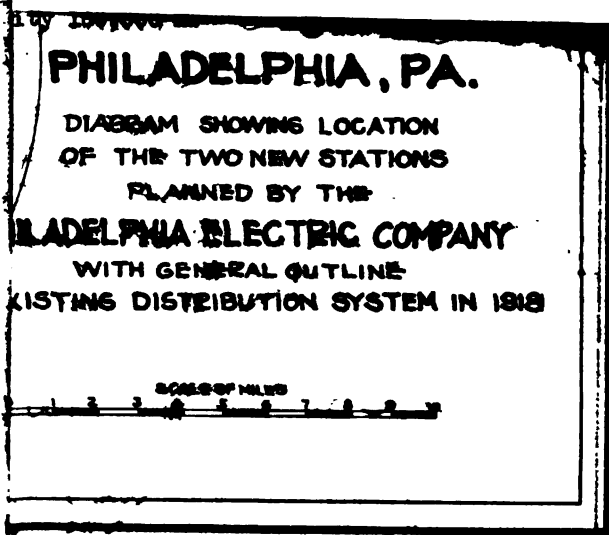
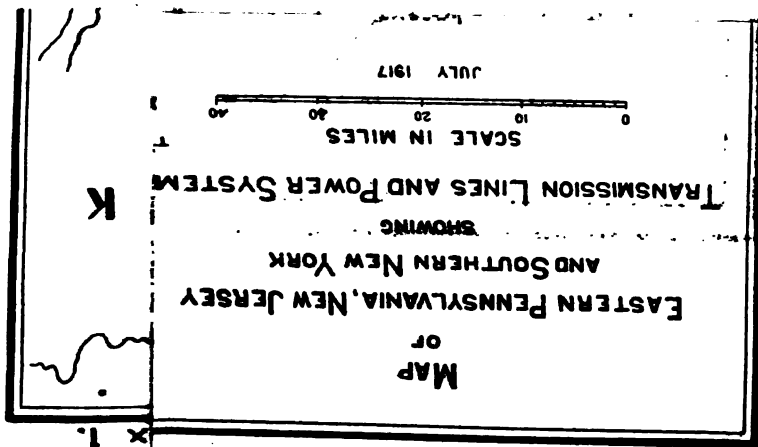
cussion arose which materially delayed financial assistance to the Philadelphia Electric Co. and which was finally closed by an actual shortage of power due to a breakdown of machinery. The discussion arose in this way: Between the time of the power section reports, quite early in the year, and the last investigation the Chester plant had been pushed to partial completion and Philadelphia had been placed in the restricted zone as to war orders. The anticipated production, therefore, had not developed and the later canvass of the power situation showed an apparent power capacity after the second Chester unit had been started of a few thousand kilowatts—15,000, approximately—more than the demand. The total installed capacity was a little over 200,000 kilowatts, and a known demand existed of 185,000 kilowatts. This situation was artificial, existing only because additional customers had been refused by the company for a considerable period, as well as for the further reason noted above. Much more load could have been operated had the generating capacity been available. The Shipping Board's investigators, however, thought that this reserve—15,000 kilowatts—was sufficient for the winter, but the event proved them in error.

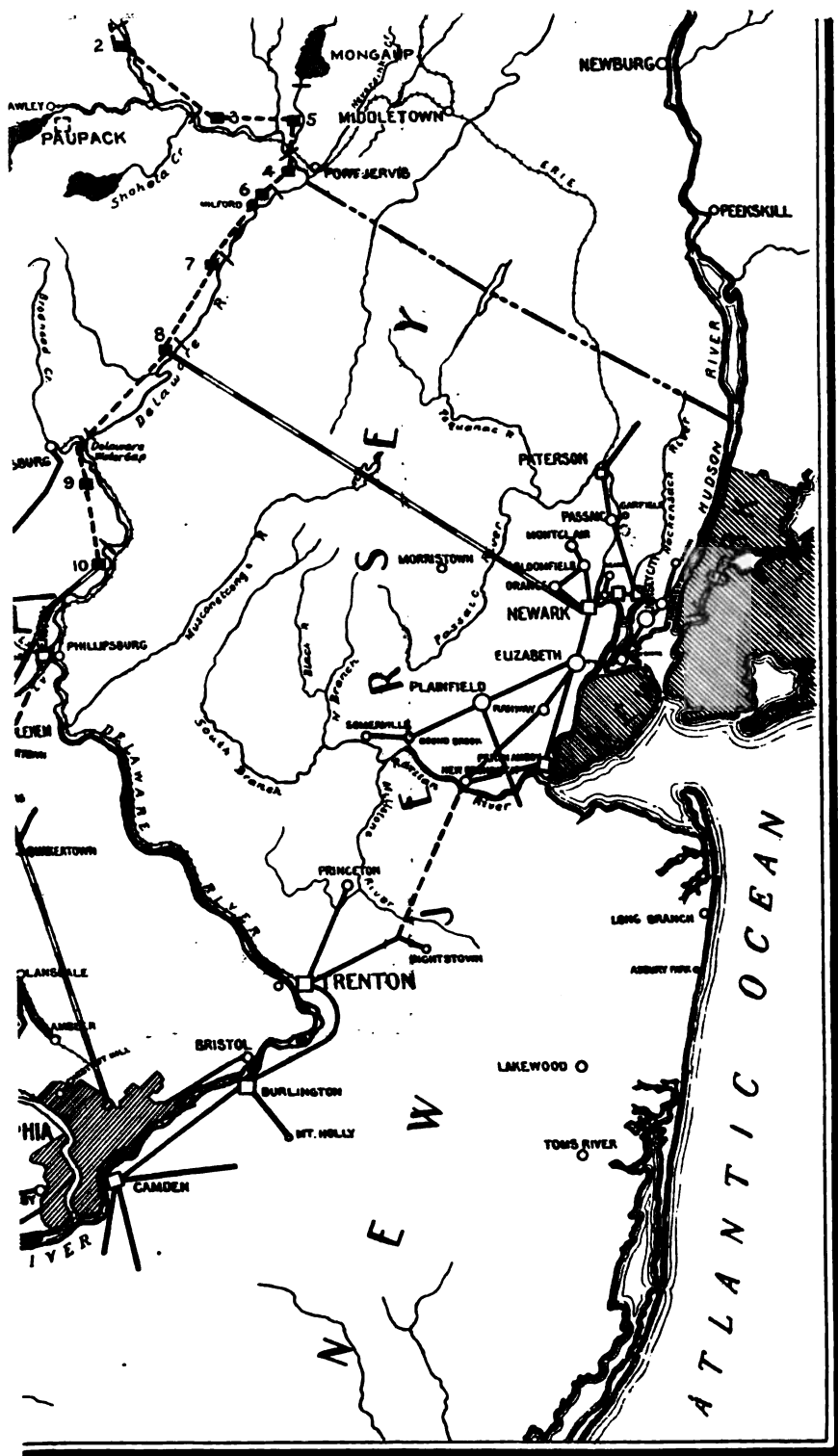
It can be readily understood that a plant of the size of the Philadelphia Electric Co., with its large number of machines and auxiliaries and its great importance to the industries and the domestic life of that city, must have large power capacity in reserve. A city of the grade of Philadelphia should never be with less than 60,000 kilowatts spare capacity; so that as barely one-quarter of this was available shortage and not excess really existed. This was soon proved by a breakdown of one large unit, 35,000 kilowatts, at Philadelphia, November 9, 1918, when a shortage developed at once. Power was then denied various less important consumers in accordance with the preference schedule of the priorities committee of the War Industries Board.

As the war was then ending no further action was taken looking toward Government aid for increased plant. A diagram showing the system and the proposed plants of the Philadelphia Electric Co. is attached, as is also another showing the districts of Philadelphia, eastern Pennsylvania, New Jersey, New York City, and Wilmington, Del., and the Delaware and Susquehanna Rivers.

THE LEHIGH NAVIGATION & ELECTRIC CO. IN EASTERN PENNSYLVANIA.

Reference has been made to the system of the Lehigh Navigation & Electric Co. operating power plants at coal mines west of Philadelphia at Hauto and Harwood. This system was originally planned for developing power from the very small sizes of anthracite coal previously not utilized. This had proved to be a considerable success and the power was supplied to coal mines, cement works, and other industries in the vicinity, as well as to the Bethlehem Steel Works at Bethlehem, Pa. The additional demands for power brought on by the war for producing coal and for the Bethlehem Steel Works exceeded the capacity of the company. It exhausted its own resources in developing its plants and was ultimately compelled





to appeal to the Government for assistance to meet the later demands of the Bethlehem Steel Co. Negotiations were in progress at the close of the war, but were so delayed that relief could hardly have been obtained in the winter of 1918-19, and a serious shortage would have existed on this company's lines.

It is obvious, of course, that under these conditions this company could have been of no aid to the Philadelphia situation, although it was considered in a great interconnected power scheme.

The same conditions as to shortage of generating capacity, lack of funds, etc., existed in connection with certain companies at Phoenixville, Pa., and Coatesville, Pa., near Philadelphia. Various attempts were made by these companies to obtain Government assistance, but up to the close of the war no such arrangements had culminated, and a condition of shortage would have existed in the ensuing winter.

WILMINGTON, DEL. AND BALTIMORE, MD.

CONDITIONS FOUND.

While quite distinct from each other, these two cities are close together in the same congested area and their power problems were closely identical. In each city the power companies furnished electric power to large and numerous works whose products were most essential to the war, among them great shipbuilding works, powder plants, arms and munitions factories, locomotive and steel works. The Government itself planned large plants in this section which required blocks of power. The problem of transportation of workers from the cities to large works on the outskirts was a further factor in the situation.

The power supply company in neither city had sufficient resources to meet the demands upon it and while only one interruption of service occurred due to lack of power at Baltimore, if the war program had continued the supply of power would have proved inadequate in the winter of 1918-19.

This was developed by inspection and study early in 1918 and confirmed by later examinations. It was found that the companies had prepared plans for expansion, but were unable to finance them fully. In both cases the companies had arranged for part of the funds necessary but were unable, under the financial conditions existing, to obtain the remainder.

WILMINGTON.

The Wilmington & Philadelphia Traction Co., the utility company at Wilmington, furnished power and transportation around Wilmington and along the Delaware River and, with its affiliated companies, covered the territory, nearly to Chester toward the north and to Newark and Delaware City in the opposite direction down the Delaware River, and further supplied certain territory in New Jersey across the Delaware from Wilmington.

Its plant contained generator capacity of 23,000 kilowatts but was limited by lack of boilers to about 13,000 kilowatts. It had carried a peak load of 14,100 kilowatts in the winter of 1917-18, but this did not represent the full load, for the company's customers by request had held off part of their load and the street railroad demand

was also low on account of cars held out of service. A number of shipbuilding and steel plants demanded additional power, one of them going so far as to supply one-third of the money required to meet its requirements.

LACK OF CAPACITY.

With the additional normal growth, the minimum increased supply required was 6,900 kilowatts. In order to furnish this, it was necessary to bring up the boiler capacity and provide an additional 10,000-kilowatt generator at a cost of about \$910,000. The company was unable to raise this sum and while it made all the improvement in its plant possible with the funds available, including those advanced by the steel company, it could not have completed the additions necessary without Government aid.

BALTIMORE.

At Baltimore the same situation existed on a larger scale, as power was supplied to Baltimore and its environs from four sources, the Consolidated Gas, Electric Light & Power Co., the Pennsylvania Water & Power Co., the United Railways & Electric Co. The Edison Electric Co., of Lancaster, Pa., was interconnected with Baltimore through the Pennsylvania Water & Power Co.

These companies covered the dense manufacturing area in and around Baltimore, including many great shipbuilding, steel, munition, copper, chemical fertilizer, and machine works, as well as the smaller town of Lancaster to the north and provided the necessary street car and interurban railway service.

CAPACITY.

They had a rated generating capacity of 173,130 kilowatts, of which about 73,280 was hydraulic and the balance, 99,850, derived from steam plants. The main steam plants were those of the Consolidated Gas, Electric Light & Power Co., hereafter called the Consolidated Co., aggregating 68,500 kilowatts. Of these the plant at Westport, of 62,500 kilowatts, is the principal one, the other plant on account of its inefficiency being operated only when great necessity arises. A small water-power plant of 400 kilowatts is also connected to the system and operated to the fullest extent. The maximum operative capacity of the Consolidated Co. in the final analysis was placed at 56,000 kilowatts. On the same basis the United Railways & Electric Co. contributed 24,000 kilowatts. The Pennsylvania Water & Power Co. is a large hydroelectric power company, whose plant is located at Holtwood, on the Susquehanna River, about 40 miles from Baltimore. It supplies power both to Baltimore and Lancaster and has a rated capacity (variable) of 72,000 kilowatts. Of this, except at low water, August and September, 55,000 kilowatts was taken as the average supply to Baltimore. This gives the continuous supply of the city as 125,000 kilowatts, which met the peak demands of 1917-18.

PROBABLE DEMAND.

In December, 1917, Baltimore had been reported by the War Industries Board as one of the cities where there was a shortage of power for manufacturing purposes and had been placed in the re-

stricted area defined by the orders of the Secretary of War. In spite of these endeavors to avoid increasing war work at Baltimore, the situation of the city and its many great industries made heavy additional demands for power to supply work that had to be done there. The restriction caused by the prohibition had diminished the estimated peak load for 1918-19 by 11,000 kilowatts, but the additional power still required was over 25,000 kilowatts for large war customers alone.

In addition to this the increasing railway load, the construction of a Government gas-shell filling plant at Magnolia and ferrosilicon requirements brought the estimated increased load for 1918-19 as figured in June, 1918, up to 51,500 kilowatts, making a total demand on the whole system of interconnected plants of 177,100 kilowatts. Still further extension of the Government gas-shell filling plant and additional shipbuilding yards were considered for 1919.

PLANS OF COMPANIES.

While a heavy increase of load on the system had been anticipated by the power companies in 1917 and 1918, such a demand as has just been described was not expected, particularly so quickly. In planning to provide for the demand the burden fell largely on the Consolidated Co. The Edison Electric Co. at Lancaster could do nothing except economize power as much as possible. The Pennsylvania Water & Power Co. had several plans for increasing capacity, but the time and money required made them unavailable. The United Railway & Power Co. made several improvements to its plants, which gave perhaps 9,000 kilowatts capacity more to the system, so that about 135,000 kilowatts was available to meet a peak load of 177,000 kilowatts.

The Consolidated Co. fortunately had ordered and practically financed two 20,000-kilowatt turbogenerators for installation in 1918 and had also ordered but not financed two more 20,000-kilowatt machines for installation in 1919. It was hoped that the 1918 machines would be installed in July and August and provide power during the low-water period of August and September. Had this been realized, it was expected to provide for the peak load of December by careful economy and temporarily shutting off power to the electric furnaces of the ferrosilicon works of a company subsidiary to the Water & Power Co., which had primarily been built to absorb the surplus water power of the hydro plant during full water periods, but at this time its output was necessary for the war. After carrying the peak of December by the installation of the two 20,000-kilowatt machines mentioned, it would have been necessary to provide for the additional war load of 1919 by installing the next pair of generators or at least one of them. This, the company could not do and it would have been compelled to apply to the Government for the money with which to do it, as its own funds were exhausted by the large increase it had just completed. Had the war continued Baltimore would have found itself using every unit of its available capacity to meet its load with no reserve for safety or repair. As a matter of fact, however, delays in the manufacture of the first two 20,000-kilowatt generators were so great that they were not installed by December 1, although one was nearly completed.

SHORTAGE.

The estimates made by the engineers of the power section were not excessive as shown by the fact that it was estimated that of the total peak in December, the Consolidated Co. would have to supply 96,000 kilowatts and in spite of the armistice the peak load in November, 1918, was 82,750 kilowatts. Had the war continued there is no doubt the power required would have been fully that estimated. It is also interesting to note that during the low-water period of the Susquehanna River a shortage of power occurred in September so that the supply of power to war industries was materially cut down and apportioned in accordance with the schedule of priority set by the priorities committee of the War Industries Board.

THE PACIFIC COAST.

Conditions as to the supply of power on the Pacific coast were investigated by Maj. Sever, of the power section of the War Industries Board, who was assigned to that section in May and remained there until the end of December, 1918. He has filed a complete report on the subject, with maps, to which reference is made for a full description of the conditions found. It is therefore unnecessary to go into the matter fully here—only the main issues are mentioned.

SOURCES OF POWER.

The question of power supply on the coast involves the utilization of water power to the greatest extent in order to conserve the fuel necessary for heating and other uses. With the exception of small coal fields in Washington, the coast had no fuel supply of this kind. The discovery of oil in the southwestern part of California has proved of tremendous value in the last 20 years, but the supply is limited, and later wells are not producing as much oil as those originally bored. Furthermore, the Government, with a view to supplying fuel to its naval forces on the Pacific Ocean, has reserved a considerable portion of the California field. The annual output of fuel oil is becoming less rather than more, and in consequence the great object is to conserve the use of this fuel for purposes for which it is indispensable and to produce the required power supply from hydraulic sources, which here abound.

SEATTLE CONDITIONS.

One of the first problems encountered on the Pacific was on Puget Sound. Here a large public-utility corporation, the Puget Sound Traction, Light & Power Co., was furnishing power along the eastern shore of the sound, and two of the principal cities, Seattle and Tacoma, were also furnishing power from their municipal systems. Great activity existed in both cities in shipyards, machine shops, electric furnaces, electric railways, mills, and foundries. In Tacoma the municipal system and the utility company's system were connected for an interchange of power, and no difficulty was encountered in supplying power. At Seattle, however, there was considerable rivalry between the utility company and the municipality and no interconnection existed. The city of Seattle had been particularly

active in supplying power for war purposes and soon found itself unable to meet the demand. There was no shortage of power on the lines of the utility company, however, and a considerable load could be provided by combining it with the systems of the two cities. One of the main power plants of the city of Seattle, at Lake Union, was burning fuel oil in large quantities, a great part of which could have been saved by interconnection with the hydraulic sources of the utility company. The main steam station of the utility company had also been changed over from an oil-burning to a coal-burning station. The city of Seattle, however, objected to interconnecting with the utility system, the difference being one of rates to be allowed the company. The city was also very desirous of developing a water supply on the Skagit River, in connection with which it proposed to build a new hydraulic power plant, which would have enabled it, in turn, to practically discontinue the use of its former water supply and power system. This would have taken a long time and in the meanwhile did not provide for the power shortage or reduce the fuel consumption at Lake Union. The interconnection between the city and the power company was therefore insisted upon and was ultimately made. This was accomplished in the following manner:

ADJUSTMENT.

The city of Seattle having sent its representative to Washington to get the permission of the Capital Issues Committee for the issuance of bonds for the building of the Skagit River plant, and the War Industries Board having been advised by the power section concerning the situation at Seattle, the board made a presentation of the case to the Capital Issues Committee and recommended that the bond issue be authorized, if at all, only on condition that an interconnection be made between the system of the city and that of the utility company. This was finally agreed to and later accomplished.

PORTLAND, OREG.

At Portland, Oreg., power service is rendered by the Portland Railway Light & Power Co. and the Northwestern Electric Co. The same industrial activity existed here as on Puget Sound, and the demand for power had reached a point where only a small surplus remained. It was estimated that additional power would be needed within a year and the development of a hydroelectric plant on the upper Clackamas River was recommended but could not be financed, although it was understood that the Shipping Board was ready to assist to some extent.

DROUGHT IN CALIFORNIA.

In California it was found that during the period from 1916 to 1918 precipitation in the mountains had been notably low. In consequence, only a small amount of water had been stored by the larger hydroelectric systems of the State, causing a shortage of hydroelectric power for the industrial districts. It was therefore necessary to operate steam stations for long periods at high loads, resulting in a heavily increased consumption of fuel oil and a higher cost

of production of power, in spite of which the hydro-power resources were gradually being depleted.

SHORTAGE AND ADMINISTRATION.

This condition continued until there was an extremely low hydro reserve on the various systems and they were in danger of a shortage. This condition was most serious in the northern part of the State, and the power companies, with the approval of the railroad commission, had appointed a power administrator for distributing the available power in the most effective manner. Power was allocated in accordance with the importance of the industry, following the procedure laid down by the priorities committee of the War Industries Board. It was necessary to curtail power to electric railways, to manufacturers of cement, for gold-dredging companies, and for hydraulic mining. Lightless nights were introduced and a few small classes of industries were shut down during the serious shortage.

The companies principally affected by deficient precipitation and storage were the Great Western Power Co., the Pacific Gas & Electric Co., and the Sierra & San Francisco Power Co. Because of financial and other difficulties none of these companies were making any addition to either their steam plants, which were situated at or near San Francisco, or their hydroelectric plants in the mountains. The short water supply during the preceding two years had changed the companies' engineering policy somewhat, in that they now found that it would be desirable to have sufficient boilers in their steam stations to develop their full electric generating capacity, but this for the moment was out of the question.

INTERCONNECTIONS.

The power administrator and the companies found it possible, however, to make interconnections between some of the companies in the extreme northern part of California and to supply some 8,600 kilowatts of power to the San Francisco section, where the principal shortage occurred. The additional demand for power had overloaded many of the transmission lines and submarine cables across the bay to San Francisco, but the companies were not able to purchase additional cables.

During the war the companies cooperated in a most excellent manner and worked together to utilize all the electric power they could develop. Several additional important interconnections besides those mentioned were made when suggested by the representative of the power section, and his recommendations as to the best possible use of power were followed in every case. All the assistance possible was given the power companies in obtaining priorities on needed materials.

It is well known that large additional amounts of hydroelectric power can be developed in the Sierra Nevada Mountains, and that the cost of development is not high. In view of the cost of fuel oil, hydroelectric power can be delivered at the industrial centers at a price much below the cost of steam-generated power. There is no

question that this plan of development should be encouraged in every way.

In this connection it should be noted that the cost of fuel oil had risen from 60 cents per barrel in August, 1915, to \$1.60 in April, 1918. The three larger hydroelectric companies mentioned in 1918 burned \$3,180,000 of fuel oil at an average price of \$1.55 per barrel. Even during normal periods the use of oil by these companies was large. Much of it can and should be saved by early hydroelectric developments.

In southern California, while shortage conditions existed, they were not as acute as in the north. The use of power was carefully watched and apportioned throughout this district. The burning of fuel oil to save water was also necessary here, although to a less extent.

LOS ANGELES SITUATION.

A situation arose at Los Angeles which, while it did not involve the question of waste of power, did involve a duplication and consequent waste of labor and materials, through competition between the Los Angeles municipal electric administration and certain utility companies, which built duplicate lines and circuits throughout the city. Under any conditions this would be wasteful; under war conditions it could not be permitted, and Maj. Sever prohibited the continuance of this practice. These orders were complied with by all the parties at interest. After the signing of the armistice, however, the War Industries Board desired to close up its work, and therefore relinquished control of this matter.

Had the drought of the two preceding years continued, very acute shortage would have been felt, but fortunately in the late summer and fall of 1918 heavy rains occurred, which gave ample water supply for the immediate future. In a way the power shortage caused by the acute drought will prove of service in that it has pointed out the insufficiency of the present hydroelectric supply, and that the available resources must be developed further as years go on to prevent a similar shortage and to curtail the use of fuel oil. The Great Western Power Co. has recently secured the funds necessary to develop one of its proposed power projects on the North Fork of the Feather River and Lake Almanor as a storage reservoir. At present two 40,000-kilowatt units will be installed. The project, including the transmission line, is estimated will cost a little over \$6,000,000, and it is hoped that similar developments will be made by other companies and the full economy of the great hydro resources of California steadily developed to provide for the future.

A table showing the present and proposed power developments of the larger companies in California is given, and a diagrammatic map is attached¹ showing the various power companies on the Pacific coast and their locations, with an index.

¹ Not printed.

Present and proposed capacities of power companies in California.

Name and location of company.	Present hydro.		Present steam.		Minimum.
	Maximum.	Minimum low water.	Maximum installed.	Idle.	
Pacific Gas & Electric Co., San Francisco...	{ R 121,600 H 122,600 }	90,000	{ A 49,000 B 5,000 C 21,000 SF 20,000 O 10,500 }	45,000 6,500 17,000 15,000 10,500	40,000 6,500 13,500 15,000 10,500
Great Western Power Co., San Francisco...	{ R 65,000 H 69,000 }	69,000	NB* 27,000	18,000	18,000
Sierra & San Francisco Co., San Francisco...	{ R 40,000 P 33,000 }	10,800			
California-Oregon Power Co., San Francisco...	{ R 25,395 H 19,310 }	16,200			
Southern California Edison, Los Angeles...	116,000	87,000	106,000		77,000
Southern Sierra Power Co., Riverside.....	35,100		8,900		
San Joaquin Light & Power Corporation...	{ R 33,060 H 32,750 }	23,665	14,000	14,000	14,000

Name and location of company.	Proposed hydro kilowatts.	Proposed steam kilowatts.		Cost of new development.	Time of completion.
Pacific Gas & Electric Co., San Francisco...	1 25,000	{ A * 5,138 C * 2,469 }	* 15,000 * 6,000	* \$52,700 * 7,200,300	{ No. 2 station, 24 years. For dyce, Spaulding, Bowman, 1 to 1 1/2 years. 2 years.
Great Western Power Co., San Francisco...	{ * 40,000 * 25,000 * 9,000 * 9,000 * 7,000 * 32,000 }	{ (7) NB* 2,500 (13) * 9,000 }	{ (7) }	6,000,000 2,710,000 3,000,000 1,541,000	2 years. 1 year. 3 years. 2 1/2 years. 1 1/2 to 2 years.
Sierra & San Francisco Co., San Francisco...					
Pitt River, Sheep Rocks.....					
California-Oregon Power Co., San Francisco...	{ (15) 16 12,500 }				
Total cost, northern.....				20,978,300	
Southern California Edison, Los Angeles...	113,000			20,000,000	1 1/2 to 2 years.
Southern Sierra Power Co., Riverside.....	8,600	(17)	(17)	5,139,000	{ 1 to 3 years; 1918 to 1921.
San Joaquin Light & Power Corporation...	{ 18 49,800 19 204,500 }			* 7,700,000 * 22,960,000	{ 1 to 4 years.
Total cost, southern.....				48,089,000	
Grand total.....				69,067,300	

1 Bear River.
2 Horsepower.
3 Kilowatts.
4 Boilers.
5 Hydro.
6 Feather River.
7 None.

8 Boilers, 10,402 horsepower.
9 Stanislaus River.
10 Generated.
11 Gain.
12 North Beach Station.
13 Pitt River.
14 Without transmission lines.

15 Proposed dam, etc.
16 No. 2 Station, Klamath River.
17 Cooling tower.
18 First.
19 Ultimate, including above.
20 Including lines and substations.
21 Ultimate.

SOUTHERN STATES.**GENERAL INVESTIGATION.**

The Southern States are served by large interconnected power companies in North and South Carolina, Georgia, Alabama, and Tennessee. The war industries particularly involved were the great cotton industry with its many branches, the lumber industry, and the iron and steel industry centering around Birmingham, Ala. Several

great nitrate plants were planned to be placed in the South by the Government, notably at Muscle Shoals and Sheffield. This district was so large and the sources of power scattered over so much territory and so united by interconnections that, after a preliminary survey, representatives of all the power companies in the territory were summoned to Washington early in 1918 by the power section, and Gen. Keller, Mr. Bulkley, and Mr. Darlington placed before these representatives the possible power requirements of the Government for nitrate plants in the southern district. Blocks of power demanded by the nitrate plants of the unit size adopted, it was found, would not be readily available. The representatives of the companies took the matter under consideration, carefully studied the situation, and presented a report to the committee at a later date showing about what could be done. While no acute shortage of power was shown, at the same time it was found that no large amounts of power were available for Government purposes.

ALABAMA.

A later study was made of the situation in the Alabama territory, particularly as to the location of a relay unit for the nitrate plant at Sheffield, in northern Alabama. The question to be decided was whether it would be placed at the Sheffield plant itself or at the Warrior plant of the Alabama Power Co., where it would not only be available as a relay for Sheffield, by means of transmission lines, but would be more useful in case of shortage developing in the steel section of this district, which was quite close to the Warrior plant. The Warrior location was recommended, but was not adopted by the Ordnance Department. A few other minor investigations were made as to interconnections and available power near Chattanooga, Tenn., and at one or two other points.

DETAILED SURVEY.

In order to definitely check up and determine the power resources of the whole district, as described by the report of the power companies already referred to, Mr. Darlington started a detailed survey of this district in the summer and fall of 1918. This survey, however, was not completed at the end of the war and was temporarily discontinued. Since then it has been taken up again and is appended hereto, marked "Appendix E."

DROUGHT AND SHORTAGE.

During the investigation made by the power section before the war ceased, due to unprecedented drought, a severe shortage of power took place in North and South Carolina. This shortage made it necessary to administer the supply of power available by applying the rules of the priorities committee of the War Industries Board. This was done by curtailing the supply of power to cotton mills and calling on all the industrial plants connected with the power system but having their own steam plants to operate them. This order applied throughout both Carolinas, Georgia, and to a certain extent to the customers of the Southern Power Co., which interchanged power with the Central Georgia Power Co., the Carolina Power & Light Co., and others operating in this district. Some difficulty was encountered in

getting individual plants in operation, but further relief was obtained by curtailing power to nonessentials and to the lower classes of essential industries until heavy rains at the end of October gave permanent relief.

NORFOLK, VA.

Investigation of the conditions at Newport News, Norfolk, and Richmond, Va., was made in the spring of 1918. The power supply of this district was furnished by plants of the Virginia Railway & Power Co., and of the Newport News & Hampton Gas & Electric Co. The Virginia Railway & Power Co. had two generating centers, one at Richmond and one at Norfolk, Va. A shortage was anticipated at Norfolk, and the company had planned the installation of a large machine at Richmond and the building of a transmission line through to connect the Norfolk system with Richmond. For local reasons it was found best to place the additional generator at Richmond and transmit to Norfolk. In May, at the time of the investigation, the company had financed this work and had the situation well in hand. Unfortunately, however, in the fall a series of accidents took place in the Norfolk plant before the interconnection had been made. Extensive repairs had to be made to boilers and no relief could be obtained from the outside. The breakdown of the steam generating capacity occurred, no doubt, on account of the increased load required by war activities at Norfolk, and not only reduced the electric power supply but seriously affected lighting and transportation. Conditions became acute, and the control of the situation was taken over by the local board of control of War Construction Activities, headed by Rear Admiral Harris of the United States Navy. The condition just described had not changed and was kept under control of the board after the armistice until the plant of the Virginia Railway & Power Co. could resume its functions.

VIRGINIAN POWER CO. AND APPALACHIAN POWER CO., W. VA.

The Virginian Power Co. supplied power for the operation of a large number of coal mines in the New River and Kanawha coal fields, its generating station being situated at the mouth of Cabin Creek on New River. This company had a generating equipment of two 8,250 kilovolt-ampere turbogenerators with sufficient steam equipment. The maximum load, however, had about reached the installed capacity and increased load was anticipated from the increased coal output and from powder plants to be installed in the vicinity. In the beginning of the year one of the generators was under repair for a considerable period, and the company were installing a second-hand machine of about the same size.

The Appalachian Power Co.'s system was to the south of the Virginian Power Co., the main generating station being about 20 miles south of the terminus of the lines of the Virginian Power Co. The Appalachian company had considerable power resources of its own and also had interchange connections with the plants of other systems in its vicinity. A survey of the locality was made early in 1918 on account of anticipated Government demands. Provisions had already been made to aid the Appalachian Co. in securing an 18,000 kilovolt-

ampere generator, and after consideration of the interconnection possibilities a strong recommendation was made by Mr. Darlington, chief of the power section for the building of a power transmission line 10 miles long between the Virginian and Appalachian systems. By this means the resources of the two power companies would have been amply sufficient for the demands upon them. On this basis it is understood a contract was made by the Ordnance Department for the purchase of power for one of its powder plants near Charleston, W. Va.—a condition of the contract being that an interconnection should be made.

LORAIN AND ELYRIA, OHIO.

These two cities and vicinity are supplied with electric power by the Lorain County Electric Co., and have no connection with any other source of power. At the beginning of 1917 the company foresaw a shortage in its generating capacity, and designed an addition of 10,000 kilovolt-amperes in one generating unit. It estimated that the cost of this plant would be a little under \$900,000, and proceeded with its construction. By the early summer of 1918 it was found that on account of the increased price of labor and materials the construction would cost nearly \$1,200,000, and the company found itself unable to finance the additional cost. By this time the demand on the station had increased to a point where it was barely able to carry its load. The company was supplying essential war industries, such as shipyards, ore docks, steel works, automobile factories, etc., and these customers and others were demanding more power. During 1918 inspections of the plant were made, which substantiated all these conditions. The company finally appealed to the Government for assistance. Their claim was carefully considered, and they were granted assistance by the War Department on the basis adopted for the West Penn Power Co., using the same general form of contract, but in this case the company assumed 50 per cent of the excess war cost, whereas under the West Penn contract the company did not assume any. The negotiations in this matter were carried to completion in September and October, in so far as reaching an agreement was concerned and having the contract approved by the necessary authorities. The company had been assured the contract would be executed and had proceeded with the work, incurring considerable expense on account of this assurance. In consequence this contract finally was approved and signed in spite of the fact the war closed during the negotiations. It was ultimately approved by the Secretary of War on February 6, 1919.

BUCYRUS AND MANSFIELD, OHIO.

When the situation in these two towns was investigated early in 1918 it was found that the interests operating the public-service company at Mansfield had an option on the plant at Bucyrus. In view of its probable sale no provisions had been made for additional demands upon it, and it had gotten into a heavily overloaded condition. The ultimate plan was that it should receive power from the plant of its purchaser, the Richland Public Service Co., at Melco, Ohio, a power station southeast of Mansfield. This company had machinery

on order sufficient for its needs as well as for Bucyrus. It would have installed this equipment and built the necessary transmission line to Bucyrus, but was unable to arrange for the necessary funds, about \$500,000. Efforts were made throughout the summer of 1918 to obtain this money through the War Finance Corporation, but these efforts were unsuccessful. At the end of September, when this condition was ascertained, Mr. Darlington recommended that the Emergency Fleet Corporation consider furnishing aid to this company, as the products of the district were slightly more urgent for that corporation than for other departments of the Government. The matter dragged along, however, until the closing events of the war, and consideration of it was finally dropped. No relief was ever given to this locality.

LITTLE ROCK, ARK.

The situation in this district as to power shortage and necessary Government aid was treated in a somewhat different manner from the others, and it is therefore noted here.

The power supply of this district came from the Little Rock Railway & Electric Co. Its generating station at the beginning of the war was obsolete and in poor condition and there were frequent interruptions to service. Early in 1918 the United States, through a chemical company, started the erection of a picric-acid plant at Picron, a short distance from Little Rock. This plant would require about 2,000 kilowatts, and to secure this it was decided that the Government should install a 1,250 and a 3,000 kilowatt generator in the Railway & Electric Co.'s plant and construct a transmission line to Picron. The smaller generator was installed and put in operation early in October. The larger machine was delivered at the works of the company, but on the signing of the armistice work was stopped. The company, with further assistance through the chemical company and the Ordnance Department, was installing a new boiler with stoker equipment and an auxiliary plant for the treatment of the water.

(Note: Part 4 is not printed.)

PART 5.

THE RELATION OF POWER TO PRODUCTION.

There can be no dispute that an increased supply of power will produce increased output, given the means of application of the power, but it is difficult to make comparisons giving the specific results that would accrue from additional power facilities in a given location because we do not have sufficient records of such cases for two consecutive periods, one without and the other with the additional power. In consequence we can only show figures of different places with different amounts of power supply and their records of production during the years of the war. In some instances, however, we can show increased output of various products as more power was provided. The rapid absorption of the increase in output of power stations from year to year of course plainly shows the increasing demand of industries in general for power for productive purposes.

For two reasons difficulty was encountered before Congress in showing that Government aid to private power plants would benefit the war output: First, the financial and economic condition of the companies, as explained in the first part of this report, was not appreciated; and, second, the information as to relative production was not then available, and while the influence of power supply upon output was clear it was as difficult to prove as an axiom. It is in the hope that it will be of value at some future time that the information now available is put down here.

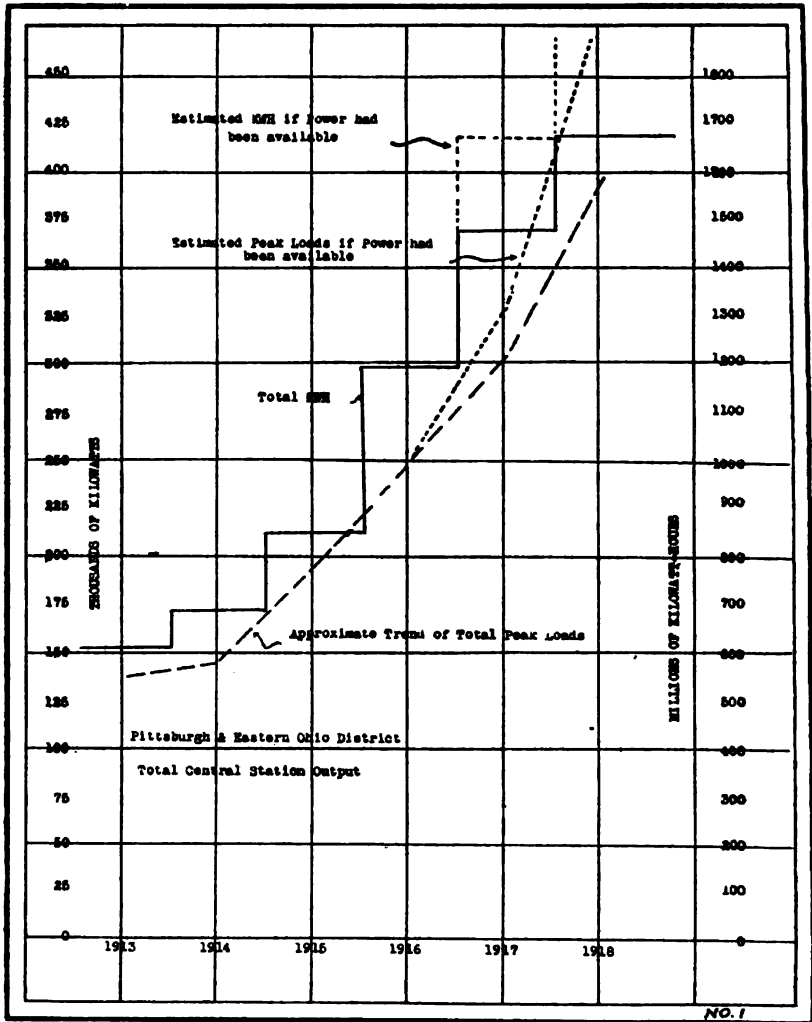
The statistics are given in general form. Except for the names of main districts and companies definite descriptions of the manufacturing companies are not given. In many cases only a final percentage statement can be submitted, as the details were given in confidence.

The increase of power described requires the development of progressively larger power plants with increased economy in operation, saving in coal, and cheapening of the final product—power. This is a most important result of the emergency problem presented by the demands of war, in that development along these lines of enlargement and economy are fundamental in conducting the competitive struggle for world trade in time of peace. The effect of the war on the power industry of the future and the proper line of progress are discussed in closing this report. In this part the results of adding power will be shown as far as may be from the data at hand.

Presentation of this data is given for two main districts—Pittsburgh and eastern Ohio and Niagara Falls and Buffalo—which are sufficient for demonstration. The same result would be found in the other districts.

PITTSBURGH AND EASTERN OHIO.

For this district, the output of the principal power plants is shown in Chart No. 1, for the years from 1914 to 1918, inclusive, which shows diagrammatically the increased output and demand or load



in number of kilowatt hours. The output for each year and the increase over the preceding year are as follows:

Year.	Kilowatt-hour output.	Increase, kilowatt-hours.
1914.....	686,240,000	
1915.....	847,430,000	162,190,000
1916.....	1,192,040,000	344,610,000
1917.....	1,466,692,000	273,652,000
1918.....	1,662,929,000	197,237,000
Total.....		977,689,000

THE POWER SITUATION DURING THE WAR.

This shows an increase in output of 142.8 per cent in four years of which nearly 100 per cent occurred in two years, 1916 and 1917.

It will be seen from the chart that after about the middle of 1916 during the two years of greatest stress, the curve of supply could follow the demand, and had not the new power plant at Wind W. Va., supplied 241,780,000 kilowatt hours of energy the actual output would have shown a much worse condition.

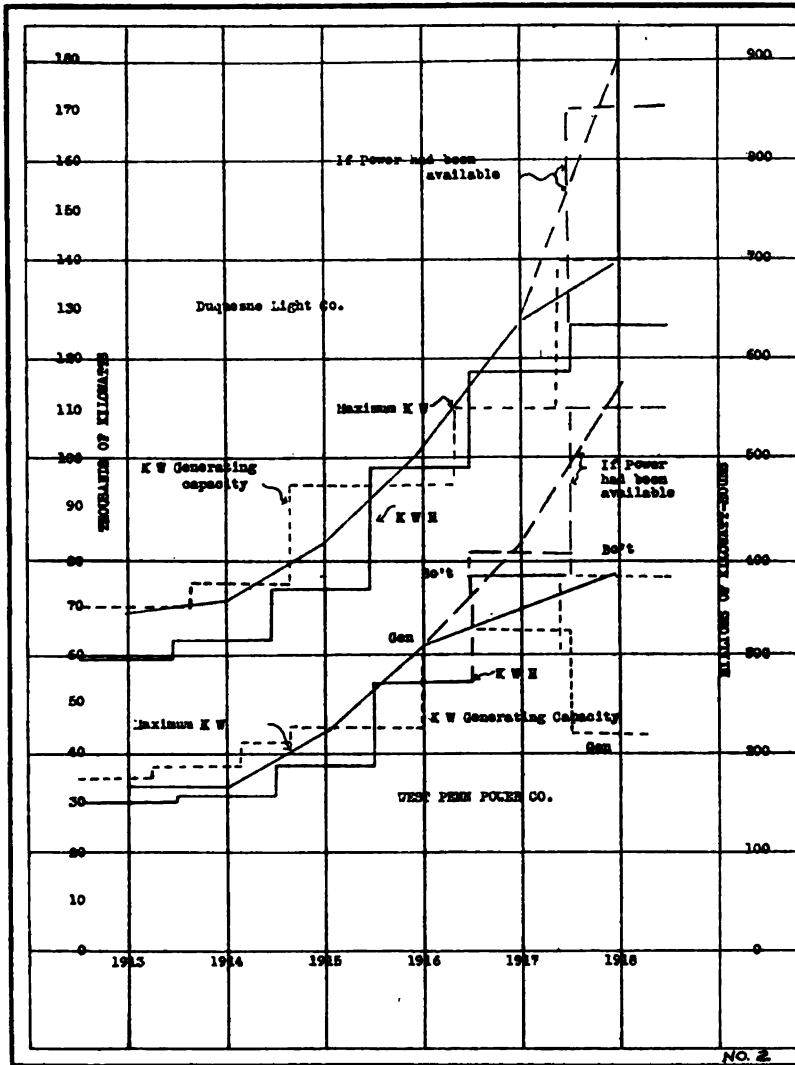
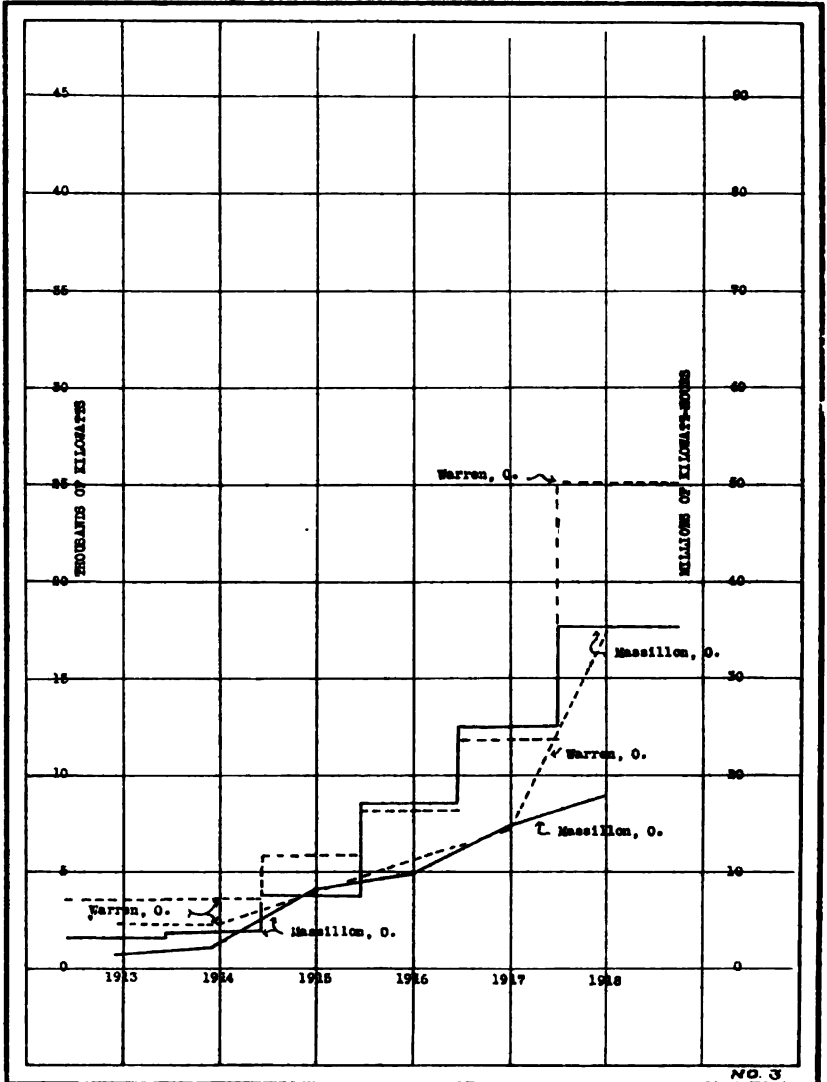


Chart No. 2 shows this in a more marked way, as it sets out condition in Pittsburgh proper and in its immediate vicinity served by the Duquesne Light Co. and the West Penn Power. The Duquesne Light Co. held its own fairly well until the mid of 1917, when, as the history of the case has shown, it could no longer keep up with the demand and the line showing actual supply dep

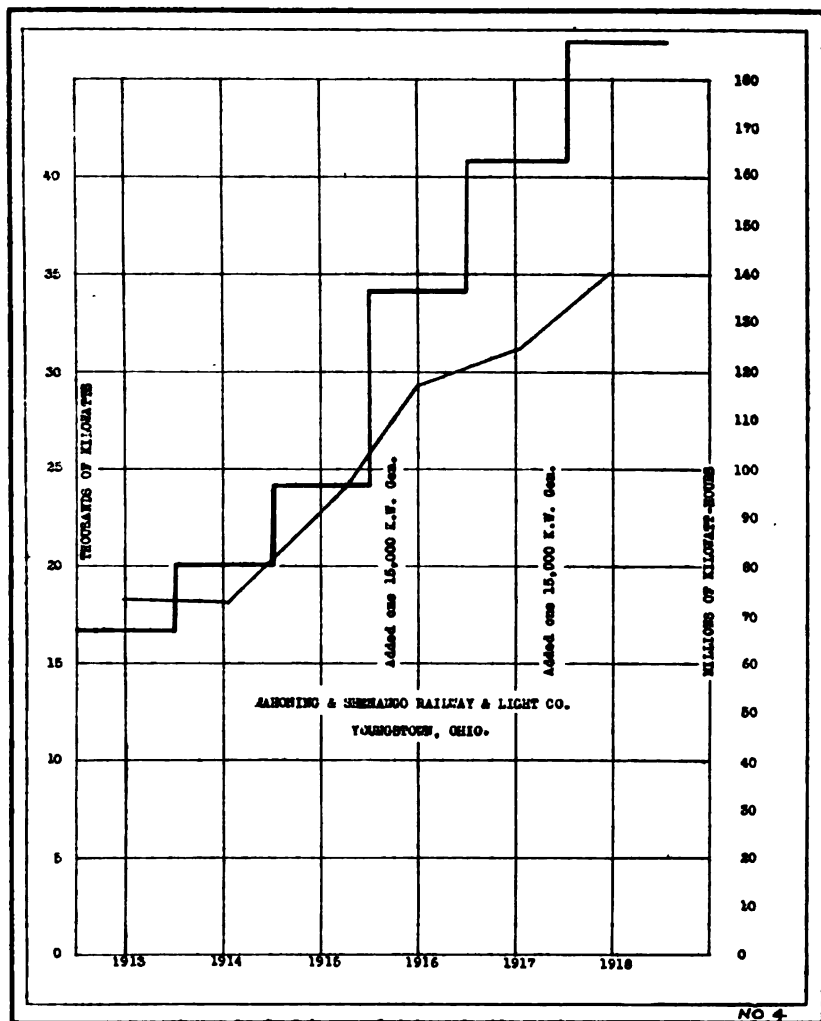
from the known demand. In the case of the West Penn Power Co., on account of need of repairs, a heavy demand for power from coal mines, etc., the point of departure of supply from demand began in 1916, continued until the end of the year, and undoubtedly affected the output of coal from its district. In each case the stepped line shows the output, the inclined full line the peak loads, and the in-



clined broken line shows when and how the demand began to exceed the output of the corresponding plant.

Chart No. 3 shows a marked example of the effect of added capacity. It represents the output of Massillon and Warren, Ohio—towns quite similar in the size of their power plants and in the industries, principally steel plants, dependent on them. They were

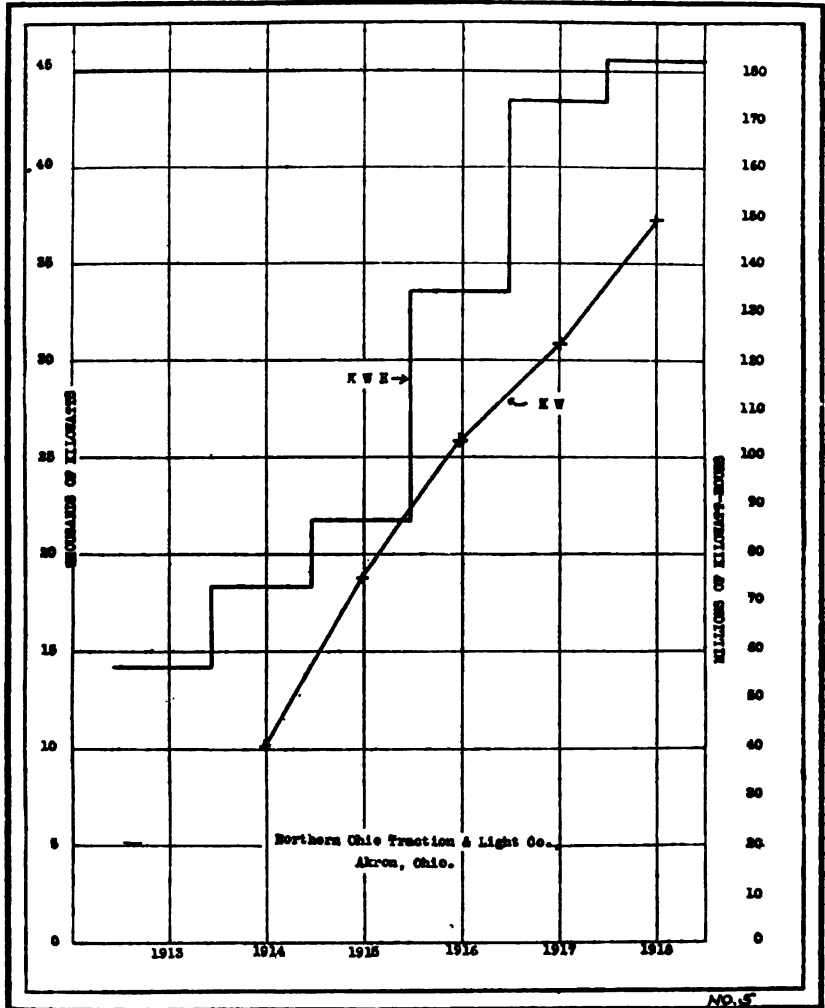
doing almost the same business in 1916, but in 1917 the plant at Warren was increased in net capacity by about 5,000 kilowatts. In 1916 its output was 16,500,000 kilowatt hours; in 1918 it was 50,000,000 kilowatt hours, three times greater; and as a coincidence this increase of 33,500,000 kilowatt hours, so made available, is almost the total amount of electric energy furnished by the company in 1918 to its three principal steel-manufacturing customers, with an aggregate finished steel product of 248,000 tons in that year.



The Massillon company, on the other hand, could not obtain funds to add to its plant and could take on but little more demand. By strenuous effort and the highest order of management and operation it succeeded in distributing its load over the 24 hours of the day, and thereby increased its output over 130 per cent between 1916 and 1918. It is known that it was never in a position to meet the addi-

tional demand waiting upon it, which was fully as high as that reached by Warren in 1918, 17,500 kilowatts. In consequence, the Massillon district fell short of the steel output it should have furnished, compared with Warren, by an amount equivalent to 15,000,000 kilowatt hours, stated in terms of tons of finished steel.

Chart No. 4 shows the development in the territory around Youngstown and the absorption of capacity when finished. In 1916 a 15,000-



kilowatt generator was installed, which enabled the plant to carry the peaks of 1916 and 1917, 9,000 kilowatts more than of 1915. At the end of 1917 the demand was still rising and another 15,000-kilowatt generator installed to meet it in 1918-19.

Chart No. 5 shows the record for Akron, Ohio. In this case by additional machinery the company had met its demand in 1917 but in 1918 could only increase its output slightly, as it was limited by

boiler capacity and lack of condensing water for increased operation. It met this condition by making arrangements, with the financial assistance of a large customer at Akron, to obtain power by a transmission line to Canton where it would connect with the large plant at Windsor. This power was not available before the armistice.

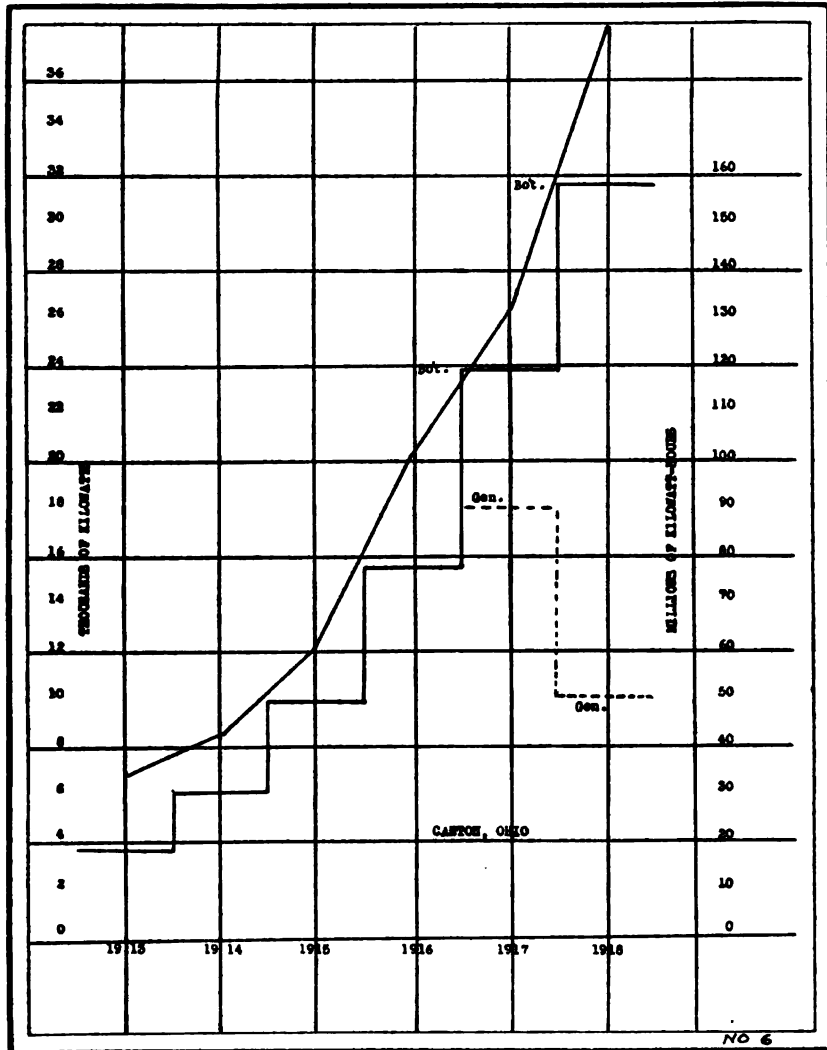


Chart No. 6 gives an example of the rapid absorption of energy when supplied, and further is the story of narrow escape from a serious shortage. In this instance, at Canton, Ohio, the utility company generated and distributed energy from its own station, but was limited in output by an insufficient supply of condensing water. The Canton power plant was also connected by transmission lines with

the large and efficient plant at Windsor, which has been so frequently referred to. It was ultimately expected to obtain the main supply of electric energy for Canton from this plant. Due, however, to accidents, delays, temporarily decreased capacity, and other insistent demands, Windsor was not able to do all that was expected of it in time. The main generator at Canton broke down and was not able to operate again at full capacity during the war. In consequence, the great increase in output shown was only obtained by the combined operation of the two stations, frequent interruptions occurred, and the two plants had difficulty in meeting the demand. Two large steel works had put in plants of their own which at times even supplied energy to the power plant. The important part that Windsor played, however, is shown on the chart. In 1917 Canton generated 90,006,000 kilowatt-hours out of a total of 119,000,000. In 1918 it only generated 44,633,000 out of a total of 158,000,000, the balance coming from Windsor.

PRODUCTION CHARTS OF DISTRICT.

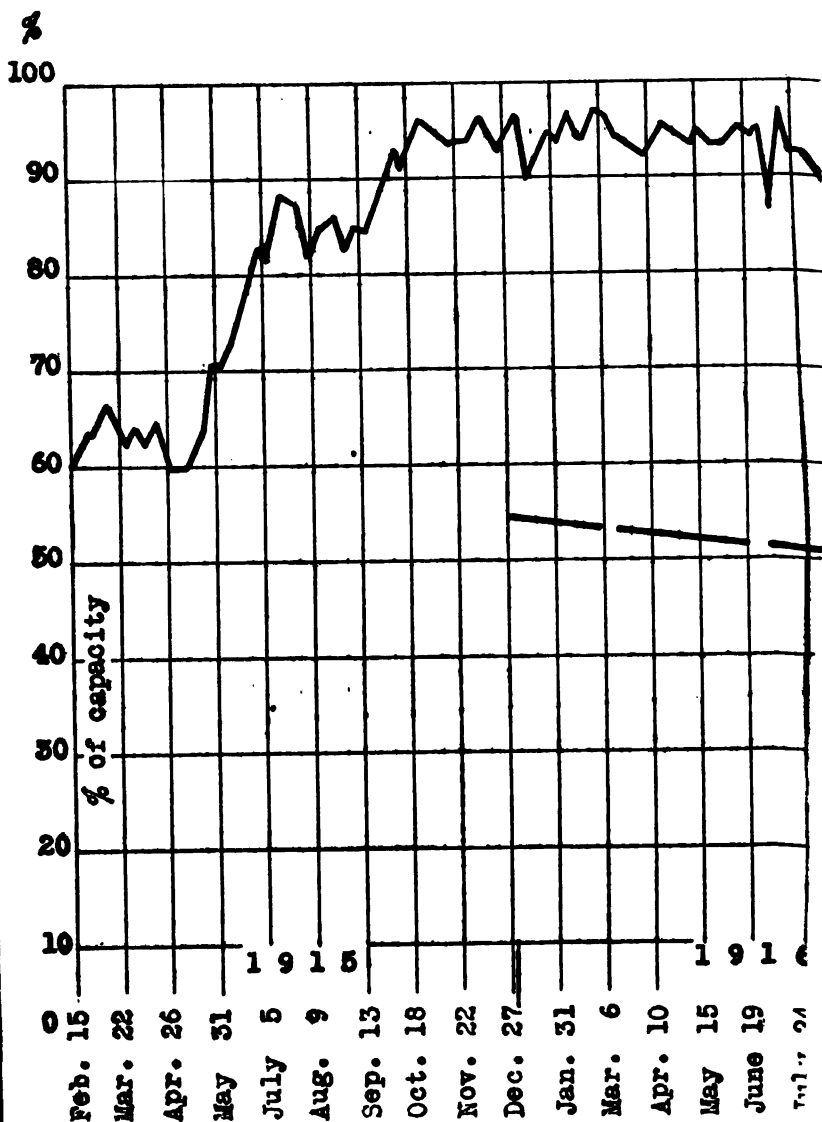
In order to show the cumulative effect of shortage of power, labor, and transportation facilities, charts were obtained showing the actual decline in output of the great staples of the Pittsburgh district steel, coal, and machinery. This occurred in spite of an increased capacity in furnaces, mining facilities, and factories. These charts show this graphically from 1915 to 1918.

Chart A shows that although manufacturing capacity rose from 15,000,000 tons in 1915 to nearly 18,500,000 tons in 1918, steel production decreased from 95 per cent of capacity in 1916 to about 82 per cent at the end of 1918. The increased manufacturing capacity, however, gave an increase of actual output in 1918 notwithstanding the reduction in efficiency.

Chart B shows that although the mining capacity increased from 60,000,000 tons in 1915 to 63,500,000 tons in 1918 the production of coal fell from an output of 93 per cent of capacity at the high point in 1915 to less than 70 per cent in 1917 and reached an average possibly of 75 per cent in 1918. Many times for considerable periods, due to strikes, weather, etc., the production fell far below these figures, materially reducing the output of coal during the two critical years of 1917 and 1918. During 1918 it is known that the power companies were never able to meet the demand for electrical energy required for coal production. Various estimates have been made of the effect of electric power supply in increasing the output of coal mines and decreasing the use of coal and labor in its production. Electric companies give statements of increase in output of 10 per cent to 100 per cent, depending on conditions—of decrease in labor of 2.5 per cent and of saving in coal of from 150 to 175 pounds per ton produced. The result of a full supply of electric power is obvious from these figures.

Chart C is a similar diagram representing the machinery output, which again in the face of increasing capacity shows a decrease in percentage of capacity utilized as well as a small decrease in actual product. It is known that in 1917 and 1918 the power supply was not sufficient to meet the demands of this industry. In all three

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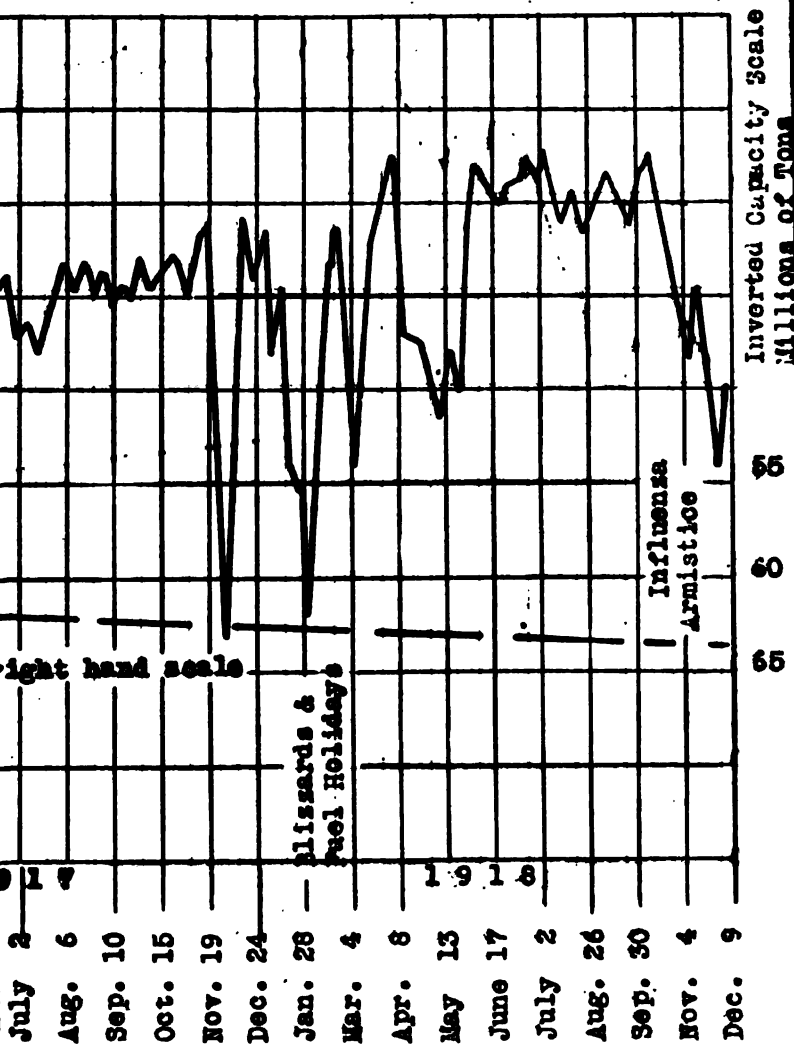
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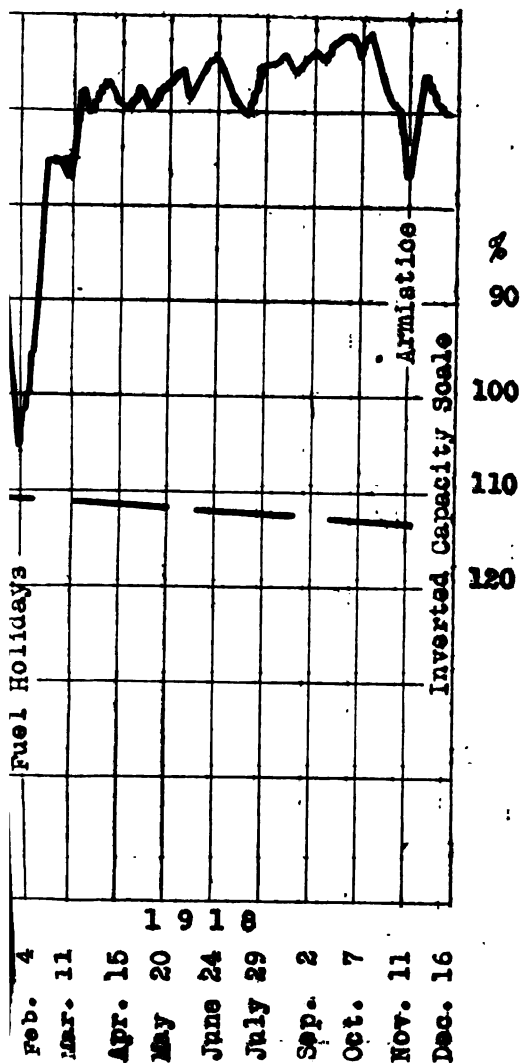
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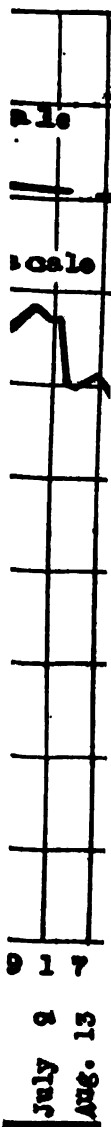




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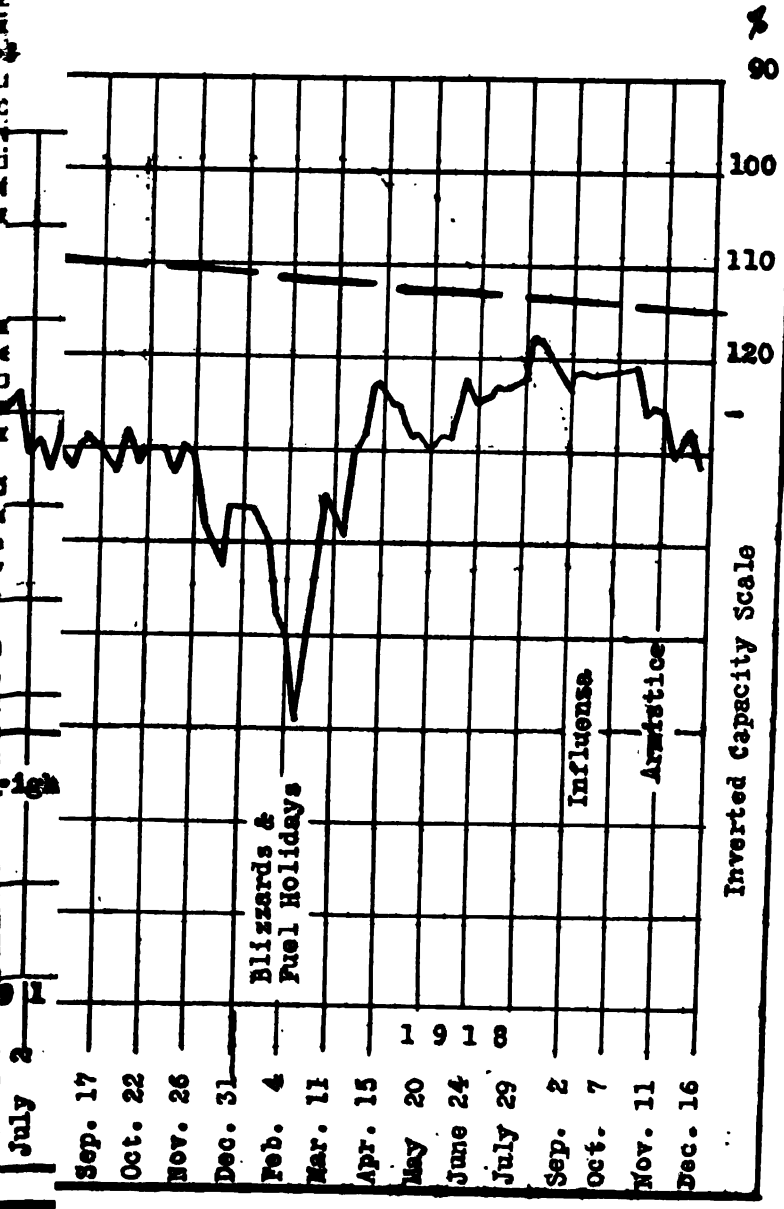


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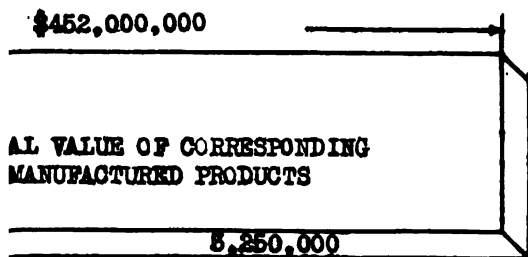
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charts the marked deflection marked "fuel holidays" means shortage of fuel and power, these holidays being declared in order to catch up in the supply of fuel, which was running dangerously low.

An independent estimate was made by the various utility companies and the chambers of commerce in the Pittsburgh and eastern Ohio district of the increased output and its value were a full supply of electric energy developed. This is shown in Chart D (Plate 2), and is based on an output of \$1,000 of manufactured product for each kilowatt-year of power used. With Chart E (Plate 1) it further gives their estimate of the size and cost of additional plant required. How the value of \$1,000 per ton of manufactured product was derived and how the tonnage output was estimated is not known. The figures of cost of plant, based on 1918 standards, are higher than the estimates of the power section of the War Industries Board.

These two charts are included here as showing the connection between power and production as developed by other agencies and tending to confirm the conclusions of this report, although the estimates in each case are higher than those of the power section. They show, in brief, that additional electrical plant of 581,250 kilowatts, costing \$50,000,000, would enable the district to increase its output 6,000,000 tons, with an aggregate value of \$818,000,000.

NIAGARA FALLS AND BUFFALO.

In this district, particularly near Niagara Falls, were clustered a number of large industries requiring great quantities of cheap power, chemicals, electrodes, ferro-alloys, aluminum, abrasives, and electric steel being the principal products. From Buffalo east to Syracuse were many other factories almost as important for war purposes.

Every means was used to obtain more power for war industries in this section, and this power was absorbed as fast as it could be secured, although it was much more expensive than that from the usual hydro sources.

From 1914 to 1918 power in kilowatt-hours per year developed by the plants situated on what might have been termed the Niagara system from Buffalo to Syracuse was:

Year.	Kilowatt-hours.	Increase.
1914.....	2,424,485,773	.....
1915.....	2,438,733,216	14,247,443
1916.....	2,767,200,550	328,467,334
1917.....	3,094,605,019	327,404,469
1918.....	3,266,905,384	172,300,365
Total.....	.....	\$42,419,611

An increase of 34.7 per cent in four years.

Of this increase the four large power companies at Niagara Falls and Buffalo, Niagara Falls Power Co., Hydraulic Power Co., Niag-

ara, Lockport & Ontario Power Co., and the Buffalo Electric Co., contributed the larger part, as follows:

Year.	Kilowatt-hours.	Increase.
1914.....	2,125,985,410	
1915.....	2,133,561,883	7,576,473
1916.....	2,391,096,399	257,534,516
1917.....	2,673,529,313	282,432,914
1918.....	2,821,218,893	147,689,580
Total.....		665,233,483

The table shows an increase of 32.7 per cent in four years, 82.5 per cent of the total increase in the district. Of this increase again the larger amount came from the steam sources of the Niagara, Lockport & Ontario Power Co. and the Buffalo General Electric Co. It will be noticed that, as elsewhere, a large increase of power had been developed in 1916 before our entrance into the war. The output in 1918 was abnormally low on account of serious ice jams in the Niagara River above the Falls in January and February.

While the power capacity added to this district was not great on account of its long average daily use, the additional quantity of power so supplied was large. It was absorbed as fast as produced, and the results show in the increased output of those products most necessary for the war.

The exact data of power and product can not be quoted, as it was given in confidence, but assuming the power used in certain industries in 1914 as unity, the proportion of increased power absorbed is given below:

Products.	1914	1915	1916	1917	1918 ¹
Chlorine, etc.....	1.00	1.22	1.55	1.87	1.82
Electrodes.....	1.00	1.48	2.22	3.98	5.57
Ferrosilicon.....	1.00	.69	.93	1.18	1.29
Phosphorus, etc.....	1.00	1.50	2.33	2.86	3.00
Magnesium.....	.00	1.00	20.57	31.74	50.12

¹ Eleven months.

In several of these industries, in spite of the power added, there was never enough to operate at full capacity.

The production of chlorine could have been increased 10 per cent further if apparatus requiring 4,000 horsepower could have been put in use. In spite of this, it is reported that 2,513 tons of chlorine and 20,577 tons of bleaching powder in excess of the normal output were shipped from Niagara Falls in 1918.

Based on incomplete returns the production of electrodes increased in 1918 over 1917 by 7,600,000 pounds.

Figures for ferrosilicon are available only for 1917-18. In earlier years the same power was used in part for other products. If additional power could have been supplied, sufficient equipment was available to have increased the product in 1918 by from 15 to 20 per cent. In spite of the small percentage of increased power shown

between 1917 and 1918, the amount of power used in this industry is so large that the added power is a considerable amount when expressed in horsepower. Rough estimates show in one case a use of 704,000,000 kilowatt-hours in a year; if an allowance of 7,000 kilowatt-hours is made for each long ton of product, the output would have been 100,000 tons, less deduction for interruption to power supply and other causes.

The production of phosphorus and its compounds increased by 86.5 per cent in 1918 over 1917.

The returns from four electric and crucible steel works in the district show an increased use of energy from 1916 to 1918 as follows:

	Kilowatt- hours.
1916 -----	12,740,645
1917 -----	27,877,432
1918 -----	43,936,281
Percentage of increase:	
1917 -----	118.9
1918 -----	57.6

In one case the output in 1918 was nearly twice that of 1916. The demand for still more power from these and other works could not be granted during the war.

Considering guns and shells, information from four works shows the production—forging and machining—in 1918 of 822,000 one hundred and fifty-five-millimeter shells with an over-all use of 9,970,000 kilowatt-hours, and output of 2,870,000 seventy-five-millimeter shrapnel shells, complete, loaded, with an over-all use of 12,960,000 kilowatt-hours, and an output of 580 seventy-five-millimeter guns using 4,200,000 kilowatt-hours.

To sum up the situation at Niagara Falls, it is desired to quote an extract from the report of Maj. R. S. Hardy, Engineers, who was stationed in the Niagara-Buffalo district during the entire year of 1918. This is an entirely independent opinion which supports the main points of this report.

Maj. Hardy states:

If 250,000 horsepower additional could have been available at Niagara Falls on January 1, 1918, and if at the outbreak of the war the fact that the power would be available had been known, practically all of this additional power would have been absorbed by the first of 1918 by electrochemical and electric furnace industries, if proper Government aid in securing materials and in financing them had been given. That is, the output of aluminum, ferrosilicon, chlorine, phosphorus, and abrasives could have been doubled.

It is hoped that these statistics, while incomplete and not exhaustive, show that as fast as the supply of power could be increased it was absorbed, and that the result was a speedy increase in product. If so, then they also demonstrate the fact that when no other resource was available every dollar put into the production of electric power by the Government would have promptly produced its quota of sorely needed munitions and equipment for the war.



PART 6.

THE SUPPLY OF POWER IN THE UNITED STATES, THE EFFECT OF THE WAR UPON IT, AND ITS COST AFTER THE WAR.

The studies and review of the power industry in the preceding parts of this report have developed certain facts leading to conclusions serious in their effect on the future supply and price of power in this country.

While the supply of power by means of electricity is principally considered because the greatest amount of energy is distributed in that form, yet the conclusions apply to all power generated from coal.

The outstanding and most serious fact is that the cost of bituminous coal in the main industrial areas of the United States has doubled since the war began and the cost of power generation has almost doubled on account of this and other increased costs. No reductions in the price of coal seem probable.

Knowing the past and present waste of fuel by the individual type of power plant, as well as the economies that can be made in the average type of smaller central-station power plants and other savings possible even in the larger plants, it seems impossible that this waste can be allowed to continue when its cost has been multiplied by two with the hope of only a slight reduction in the future fuel costs.

The engineering remedy is known. It consists of the centralization of steam electric-power generation in large and efficient plants at the most economical places of production; the development of economical water power, although this will always be a smaller source of power than steam; and the efficient distribution of power from these power centers and combinations of them.

This remedy, however, requires the permanent investment of money in large amounts. To induce the flow of money into the business of power production requires the same incentive as in any other business, viz, a reasonable return on the investment with a prospect of reasonably increased profits obtained from improvements in equipment and operating methods.

Our laws do not at present furnish much incentive to encourage rapid progress in the saving of fuel and the production of cheap power.

This part of the report endeavors to show the increased costs of power throughout the country and, in view of the probable continuance of the present cost over a period of years, suggests an investigation with a view to changes in our present practice and policy. To do this the subject is developed in the following order:

1. The present and prewar cost of fuel as delivered to power-generating stations in the sections of the country studied by the power section. Its effect in increasing the cost of power and the reason for its remaining at a high level in the future.

2. The growth and increasing use of electric power by the industries of the country as supplied from central electric stations.

3. The present relative waste of our fuel resources in producing steam and electric power and the necessity for the development of our hydraulic sources of power. The further fact that these are limited in our main industrial sections and will not only produce the smaller portion of the required power supply, except on the Pacific coast and in the Southern States.

4. The change of the method of more or less individual power production to one of centralization and cooperation by interconnection.

5. Notes on the effect of the present national and State laws relating to centralization, rate regulation, and natural resources, with a suggestion of the necessity for providing an incentive for saving coal and producing cheap power.

6. The effect of cheap power on production and wages in this country and its importance in world trade.

(1) THE PRESENT AND PREWAR COST OF FUEL AS DELIVERED TO POWER-GENERATING STATIONS IN THE SECTIONS OF THE COUNTRY STUDIED BY THE POWER SECTION—ITS EFFECT IN INCREASING THE COST OF POWER AND THE REASONS FOR ITS REMAINING AT A HIGH LEVEL IN THE FUTURE.

In the fall and winter of 1916-17 a severe shortage of coal was generally feared and a great rise in prices occurred due to the sudden and alarmed demand. Bituminous coal rose in price from \$1.50 or \$2 per ton to \$5 and \$6 and higher. Contracts for the year 1917 could only be made at figures averaging from \$3 to \$5 and \$6.

As a result an investigation of the bituminous-coal situation was begun in May, 1917, by the Secretary of the Interior and the Council of National Defense, in consequence of which a price was set throughout the country of \$3 per ton at the mines, with a selling commission of 25 cents a ton to the wholesalers.

In August, 1917, Congress passed H. R. 4961, generally known as the Lever Act, which authorized the fixing of the price of coal and coke.

Under this act, on August 21, 1917, the President announced new prices on bituminous coal at the mines throughout the United States, which, for run-of-mine coal, ranged from \$1.90 to \$3.25 a ton, and were generally much below the prices previously set by the Secretary of the Interior and the Council of National Defense.

On August 23, 1917, the President appointed Mr. H. A. Garfield Fuel Administrator and delegated to him the powers conferred by the Lever Act, and thereafter the Fuel Administration took charge of the situation. On this date the President fixed prices for Pennsylvania anthracite coal. Except for two raises in wage scales, these prices on anthracite remained unchanged. The price of anthracite at the mines at the end of 1918 was about 30.5 per cent over pre-war prices.

As bituminous coal is generally used in the central station generation of power, it should be understood that, unless special mention is made, the statements made cover this kind of fuel.

The Fuel Administration made various revisions and adjustments of the President's prices until, in January, 1918, an advisory board of engineers was appointed to study and review costs and advise the administrator. A raise in the wages of miners had occurred shortly before the war, one was granted during the war, and the costs of supplies for mining increased with the general advance of materials. In addition to these increasing costs at the mine, the Railroad Ad-

ministration increased its freight rates about 25 to 30 per cent early in its career.

It would be very difficult to trace in detail the effect of these changes and adjustments, so that in order to demonstrate the actual result of an increased cost of fuel and of power the prewar and present prices of fuel, as given by the central stations of the several districts described in this report, are quoted here.

District.	Coal (short tons)	
	Prewar prices.	1918 prices. (about present prices.)
Niagara-Buffalo (Buffalo to Syracuse).....	\$2.442	\$4.822
Pittsburgh-Eastern Ohio:		
Central stations.....	1.500	3.412
Private industrial plants.....	2.00	4.00
Cleveland, Lorain, Toledo.....	1.714	3.894
New England.....	3.56	7.31
New York City-New Jersey.....	2.90	5.80
Baltimore, Wilmington, Philadelphia.....	2.785	5.08
The Southern States.....	2.634	4.923
	1.20	3.10
	2.65	3.80
The Pacific coast.....	Fuel oil per barrel. 0.70	1.65

By applying these prices to the energy output and the tonnage for 1918 to which they individually belong, we get the increased cost of power generated by fuel for a considerable portion of the total output, as shown in the table following:

Table showing effect of doubled cost of coal—Actual coal consumption and cost in 1918 of the largest power-generating plants east of Indiana and north of Virginia with comparative cost of average prices for coal prevailing in 1915.

Location.	Kilowatt-hours generated in 1918.	Short tons coal used.	Pounds coal per kilowatt-hour.	Cost per short ton.		Total cost.		Difference.
				Prewar.	1918.	Prewar.	1918.	
New England (6 States 97.8 per cent of total steam generated).....	1,283,000,000	1,806,000	2.5034	\$3.5609	\$7.3138	\$5,718,805	\$11,745,963	\$6,027,158
New York City (New York Edison and United Cos. plants only close estimate)...	958,878,000	1,060,000	2.2	2.90	5.80	3,074,000	6,148,000	3,074,000
New Jersey (Philadelphia, Wilmington public utilities plants)....	1,515,944,000	1,946,397	2.566	2.743	5.015	5,339,158	9,761,553	4,422,395
Baltimore.....	210,914,000	265,912	2.52	2.41	4.84	640,847	1,289,008	648,161
Buffalo, Lyons (Rochester, Geneva, public utilities plants).....	432,070,000	499,337	2.31	2.44	4.819	1,218,513	2,405,016	1,186,503
Cleveland (Toledo, Lorain, public utilities plants).....	604,868,000	821,993	2.364	1.714	3.872	1,409,315	3,172,839	1,763,524
Pittsburgh (Eastern Ohio public utilities plants; Windsor omitted; not operating before war).....	1,509,316,000	2,422,255	3.2	1.509	3.412	3,655,895	8,266,057	4,610,162
As an exhibit of individual plants 258 industrial plants at and near Pittsburgh show.....	6,604,990,000	8,631,894	2.61	2.442	4.962	21,056,533	42,788,436	21,731,903
	549,934,000	2,565,256	9.3	2.00	4.00	5,130,512	10,261,024	5,130,512

From these figures it is seen that the fuel cost of power generation has more than doubled. This fuel cost applied to central stations is normally about 45 to 65 per cent of the total production cost. The higher prices of fuel raise this percentage to 65 to 80 per cent of the present generation costs, and with the increased labor and supply costs that have come it may be safely stated that the prewar production cost of power has increased at least 90 per cent, if it has not actually doubled. In some known cases, where fuel costs have tripled, it has more than doubled.

The query at once arises: Will this increased cost of fuel continue? The base of the increased cost is labor. From the statements of the Commissioner of Immigration, made in December, 1918, a labor shortage may be expected for some years. The immigration of 10 years prior to the war was 10,120,940, or 1,012,094 per year. During the four years of the war it was 1,021,547, or 255,386 a year, a decrease of 3,111,584 in four years. The Commissioner of Immigration further forecasts that "with the coming of peace the United States will change from an immigrant nation to an emigrant nation." The prediction is based on the application of over 1,250,000 aliens for passage to Europe after the war.

The losses of men in England, France, Italy, Germany, Austria, and Russia have been so great that emigration will be strongly discouraged and the supply of men to our labor market will not become normal for many years. Our own loss of labor in the war we can assume to be merely temporary and capable of readjustment as our soldiers are dismissed from the Army.

It is a known fact that after waves of great industrial activity and advances in wages, while the rates of pay may fall again, they do not return to their previous level.

The price of coal has been advancing slowly and steadily for a long period. Concurrently with the increased prices of coal lands and increased royalties, the most easily mined coal as well as that commanding the best price is being worked out first. All this tends toward higher prices for fuel and in consequence for power. Consultation with expert coal engineers who established Government prices during the war, and who are in touch with the coal situation in the country, yields the opinion that the prices of coal will not be reduced on an average of over 40 per cent from the present prices unless some heavy reduction occurs in labor and in freight charges, neither of which is anticipated. The possible reduction of 40 per cent can only take place slowly over a period of years. Moreover, grave doubt exists whether such a reduction will be permanent.

If these facts are given due consideration, the conclusion that the cost of power has been greatly and definitely increased can not be avoided.

(2) THE GROWTH AND INCREASING USE OF ELECTRIC POWER BY THE INDUSTRIES OF THE COUNTRY AS SUPPLIED FROM CENTRAL ELECTRIC POWER STATION.

It has been noted in this report how power supply by large central electric stations has developed since the beginning of this century. The ability to transmit power for long distances greatly increased the area of usefulness of a central electric power station.

The development of the steam turbine and electric generator and improved steam and firing appliances greatly reduced the cost of generating electric power by steam. With these improvements and its many other advantages, due to wholesale generation, the central station could make power cheaper than the individual plant. At first it competed with the smaller individual plants; then, as its capacity increased, it competed with the larger ones. The convenience of electric power service causes it to be preferred to other kinds of power, usually at equal rates and frequently at slightly higher rates. This advantage of the central station is enhanced when the investment and overhead expenses of the individual plant are properly considered as a part of the cost of power. The importance of the time element during the war and the saving of time possible by the installation of motors and connection to central-station supply was a great incentive to the use of central electric power. This is shown in the statistics of the industry since 1914, and the increased demand for electric energy, principally for power, since 1912 is indicated by these statistics and those of the census from 1902 to 1917.

Since the first part of this report was written the census report of the electric industry for 1917 has been issued, and it supports the figures given herein. The great difference in the two sets of statistics is in the gross revenue. These totals do not agree, but both show steadily decreasing gross and net returns per kilowatt-hour. The census figures are given herewith, as well as the returns for the year 1918 from the statistics of the industry.

While the great increases of 1915-1917, under the impetus of the war, may not be repeated, yet they predicate a healthy growth in the future based on the present wider knowledge of the advantages and conveniences of electric power. These figures seem to bear out the proposition that electric energy is becoming the principal source of industrial power in this country. It will be borne in mind that the figures given cover central supply stations only, and do not include the large amount of electric power generated and used in the many private plants throughout the country.

Per cent increase.

Year.	Number of stations.	Kilowatt capacity installed.	Kilowatt-hour output.	Output for 5-year periods.	Gross revenue per kilowatt-hour.	Net revenue per kilowatt-hour.
					<i>Cents.</i>	
1902.....	3,620	1,212,235	2,307,051,000	-----	3.41	1.708
1907.....	4,714	2,709,225	5,962,276,000	95.9	2.59	1.707
1912.....	5,221	5,134,689	11,532,963,000	96.7	2.43	1.45
1917.....	6,541	9,001,872	25,438,611,000	119.9	2.07	1.39
1918.....	* 6,632	No data.	29,512,359,000	{ † 116.01 ‡ 155.8	1.79	(*)

† Figures from census.

‡ Estimated.

* 1917-18.

† 1912-1913.

‡ Unknown, but still increasing.

Comparing these census figures with those from the statistics of the industry for 1918, see p. 37.

(3) THE PRESENT RELATIVE WASTE OF OUR FUEL RESOURCES IN PRODUCING STEAM AND ELECTRIC POWER AND THE NECESSITY FOR THE DEVELOPMENT OF OUR HYDRAULIC SOURCES OF POWER—THE FURTHER FACT THAT THESE ARE LIMITED IN OUR MAIN INDUSTRIAL SECTIONS AND WILL ONLY PRODUCE THE SMALLER PORTION OF THE REQUIRED POWER SUPPLY, EXCEPT ON THE PACIFIC COAST AND IN THE SOUTHERN STATES.

By the term relative waste is meant the excess consumption of fuel in plants where the best performance is being obtained considering their characteristics as compared with what would be used in the most economic plants now practicable when operated in combination with others. It also includes the coal used for the reason that feasible water powers are not utilized.

The table gives a concrete illustration of what waste there may be even among large plants. The average use of coal per kilowatt hour by these plants is 2.61 pounds. Were this reduced to 1.8 pounds per kilowatt hour, which is quite possible, \$13,000,000 would be gained by a saving of 2,676,000 tons of coal, at an average price of \$4.962 a short ton. This amount would pay the fixed charges on an investment of \$110,612,000.

Were this reduction further applied to the individual industrial plants, as shown by the example of 258 of these plants in the Pittsburgh district, the saving would be enormously increased, making full allowances for transformation and distribution losses. Similar waste is believed to be true of a large number of the smaller individual plants in this country. It will undoubtedly be noted that the comparisons are limited to a small number of stations, generally of large size, in the eastern industrial area of the United States that are geographically described as east of Indiana and north of Kentucky and Virginia. It was in this area that the greater shortages of power occurred during the war. It was only in this way, with the facilities available, that actual figures could be obtained without using estimates or approximations which might affect conclusions. It should be borne in mind, therefore, that these figures represent—

First. Only a fractional part of the industrial use of fuel for power purposes.

Second. That they include only the most efficient users of fuel among those generating electricity for industrial purposes.

In consequence they indicate that far greater relative wastes and excess costs exist throughout the country.

There appears to be a popular idea that the fuel and power problem will be solved when the water powers available have been fully utilized. This is a fallacy so far as the area described is concerned. The data given by the United States Forestry Service shows that, in round figures, 32,000,000 horsepower of prime movers was used in the area east of the Mississippi; that in this area 12,000,000 horsepower was available as latent water power, if it may be so designated, but that to date only 4,700,000 horsepower had been utilized. There is a great difference, of course, between this amount of latent water power, so called, and the amount actually capable of present economical development, so that much of this total may not be utilized in a period affecting the present problem. At best, if all this 12,000,000 horsepower were available on the instant we would

still have 20,000,000 horsepower, with all additional power needed in the future, to generate with fuel.

It will be seen, therefore, that these water powers are a minor factor in the power problems of the future in the territory under discussion. This is fortunately not true of other sections of the country—the Pacific slope and the South. This is still further accentuated in considering some specific problems in centralization and conservation in the production of power.

(4) THE IMPROVEMENT OF METHOD FROM MORE OR LESS INDIVIDUAL POWER PRODUCTION TO ONE OF CENTRALIZED CO-OPERATION BY INTERCONNECTION AND CONSERVATION.

A process of growth and concentration sufficient to materially improve present conditions must necessarily be slow and organic, built up step by step. It will never be finished; there will always be another step. For various reasons there will always be a number of plants operating individually, but collectively a great saving of fuel can be made. Briefly, the production of power at low cost will be accomplished by building power plants of 100,000 to 200,000 kilowatts capacity or more at points carefully selected for the most economic and efficient generation and distribution of electric energy. The locations and methods of generation and use will be selected after an intensive and exhaustive study of all the factors bearing on the problem, such study, of course, including consideration of the economy of the available water powers compared with steam plants developed at their most economic points. The most efficient method of the use of fuel for power generation at each location will also be determined, with a view to the value of possible by-products.

The industrial area of this country, speaking generally, is between the Mississippi River and the Atlantic coast, with its main concentration along a broad belt back of the coast line. The principal producing sections of this area from the power standpoint are already clearly defined. The sections considered in this report include all the important ones except those along the Mississippi and between that river and the western boundary of Ohio.

The studies made of these sections during the war were elaborated after the armistice under the direction of Gen. H. Taylor and Mr. F. Darlington, by officers most familiar with them during the war period, into reports describing in a preliminary and suggestive form centralization projects for the production of large amounts of cheap power to meet the estimated future demands. Such reports were made on the New England section, New Jersey, Philadelphia and eastern Pennsylvania, the Southern States, and Pittsburgh and eastern Ohio. Maj. R. S. Hardy has made a summary report on the Buffalo-Niagara section, which includes the possibilities in that district, and Maj. Sever in his report has covered the Pacific coast.

For full details of all these projects reference must be made to the reports themselves but some important notes and suggestions on certain areas are given here.

In these sections it may be said centralization has begun, in some in a small way, in others on a larger scale. Each section may be said to be complete in itself and would have little, if any, power to spare adjacent sections.

NIAGARA—BUFFALO.

Economy in the use of fuel for power in the Niagara-Buffalo district is purely a question of the amount of water allowed to be diverted from the Falls and of the efficiency of its utilization. The war drew particular attention to this matter because of the lack of sufficient power in the district for war purposes. Two hundred and fifty thousand horsepower more could have been used but treaty and other restrictions prevented any early increase in the amount developed. The urgency of the demand for more power, however, directed special attention to this matter on both sides of the boundary. This resulted eventually in plans being approved by the War Department for the efficient use of almost the entire 20,000 cubic feet per second allowed to be diverted in the United States. This would have added about 150,000 horsepower to the supply existing, but while the work was begun none of it had been completed before the armistice.

The Canadians also took up plans for increasing the efficiency of the use of their allotment of water, and construction was begun by the Hydroelectric Commission of Ontario on the Chippewa-Queens-ton development to utilize 10,000 cubic feet per second, obtaining 300,000 horsepower with this amount of water. This would not all be additional power, however, for part of the water now used by the Ontario Power Co. will be used in the new project. It was stated that this plant would be completed to the above extent by 1921, or say three years after the end of the war.

A complete study of the ultimate development of Niagara Falls is being made by Col. J. G. Warren of the Corps of Engineers, the district engineer at Buffalo, which will be presented to Congress in due course. This will give a well-considered plan to utilize this great water power to the fullest extent compatible with the preservation of its scenic effect. It is to be hoped that this great and economical source of power may be fully utilized for the benefit of the Nation's industries so that until the demand for power again exceeds the hydro supply the necessity of operating the steam power plant of the Buffalo General Electric Co. at Buffalo as well as steam plants of poorer economy in a number of communities from Syracuse to Dunkirk, N. Y., may be obviated. Including Buffalo, five of these plants used 499,000 tons of coal in 1918 at a cost of \$2,408,000. Nearly all of this coal can be saved as soon as sufficient additional power is available from the Falls. The use of this fuel in this district in the future as in the past is pure waste as long as water that can be diverted without losing the scenic effect of the Falls is not used.

PITTSBURGH—EASTERN OHIO.

The Pittsburgh and eastern Ohio district shows the worst fuel economy and an increased cost of 126 per cent over prewar prices of coal. In the figures in the table a plant has been omitted which is an excellent example of the centralized type distributing energy over a considerable area. The reason for its omission is that it did not operate prior to 1918 and would therefore distort the comparative-cost figures for the whole area if inserted. In 1918 it generated 241,780,000 kilowatt-hours at a coal consumption of 1.8 pounds per kilowatt-hour. This was done under very adverse operating condi-

tions and may be surpassed by a considerable percentage in the future. If the supply of electric energy in this industrial area were furnished mainly by six interconnected plants of this type, which is entirely practicable, the saving from the central stations alone would be 1,056,000 tons of coal per annum, costing \$3,604,000. If the use of coal by the individual industrial plants could be reduced to this economy the saving would become very large—over \$10,600,000 per annum. It is understood, of course, that these savings could be realized only in part, but the industrial plant data obtained represents only a small part of the total number of these plants existing in this district, so that the saving of \$10,600,000 is not as impossible as it may seem at first glance.

CLEVELAND—TOLEDO.

At Cleveland, Toledo, and Lorain further economy in steam production, extension of larger centralized plants economically interconnected as far as practicable, and the consequent reduction in number of individually operated industrial plants must be looked to for increased economy in the face of highly increased fuel costs. In these centers fuel increased 125 per cent over prewar cost.

NEW ENGLAND STATES.

In New England the total electric power generated by steam, water power, and internal-combustion engines from 1915 to 1918 is given in the following table:

TABLE C.—*Kilowatt-hours (or equivalent) generated, classified by sources.*

Source.	1915	1916	1917	1918
Steam.....	3,952,294,000	4,915,610,000	4,439,247,000	4,568,847,000
Water power.....	2,063,700,000	2,262,265,000	2,308,196,000	2,364,045,000
Internal-combustion engines.....	827,000	1,073,000	178,000	212,000
Total.....	6,021,821,000	6,458,953,000	6,474,621,000	6,933,104,000

And its uses were as follows:

TABLE B.

CLASSIFICATION OF BUSINESS.

Reference No.	Class.	Number of systems or companies represented.
1	Electric street railways.....	23
2	Electric light and power.....	193
3	Railroads—electrified section.....	1
4	Steam power plants—manufactures.....	25,000-
5	Hydraulic power plants—manufactures.....	30,000-

KILOWATT-HOURS (OR EQUIVALENT) GENERATED—CLASSIFIED BY BUSINESS.

Reference No.	1915	1916	1917	1918
1.....	629,762,000	677,769,000	709,808,000	610,984,000
2.....	1,320,728,000	1,885,494,000	1,909,924,000	2,174,399,000
3.....	101,331,000	85,690,000	87,889,000	77,811,000
4.....	2,490,000,000	2,520,000,000	2,550,000,000	2,580,000,000
5.....	1,490,000,000	1,490,000,000	1,490,000,000	1,490,000,000
Total.....	6,021,821,000	6,459,963,000	6,747,621,000	6,933,104,000
Annual per cent increase.....		7.3	4.5	2.7

From this it appears that only the electric light and power stations are showing any tendency to increase their outputs. Among the causes for this are the following: The doubled price of coal, inability to secure apparatus, and the lower cost of power from the public utility companies.

It is estimated that the future demand for the production of energy in the next six years will be about as follows:

TABLE H.—*Future energy production—Tabulation indicating estimate of millions of kilowatt hours (or equivalent) to be generated during the next six years.*

Source.	1919	1920	1921	1922	1923	1924
Steam:						
Street railways.....	630	630	630	630	630	630
Electric light and power.....	1,467	1,764	2,095	2,565	3,121	3,852
Railroads.....	77	77	77	77	77	77
Manufactures.....	2,580	2,610	2,640	2,650	2,660	2,660
Hydraulic:						
Street railways.....	12	12	12	12	12	12
Electric light and power.....	1,054	1,177	1,340	1,450	1,590	1,665
Manufactures.....	1,490	1,492	1,502	1,512	1,522	1,532
Total.....	7,310	7,762	8,296	8,806	9,612	10,428
Annual per cent increase.....		6.2	6.9	7.2	8.1	8.5

To supply this amount of energy the maximum possible hydraulic developments are:

State.	Kilowatts.	Kilowatt-hours.
Maine.....	258,120	905,500,000
New Hampshire.....	155,742	494,019,000
Vermont.....	71,459	240,914,040
Massachusetts.....	70,438	299,779,000
Connecticut.....	46,000	145,000,000
Total.....	601,759	2,085,212,040

But of these maximum possible developments only the following are commercially feasible in the next six years:

State.	Added kilowatts.	Added kilowatt-hours when completed.
Massachusetts.....	62,500	271,000,000
Maine.....	116,490	683,000,000
Connecticut.....	44,000	138,000,000
New Hampshire.....	37,500	120,000,000
Vermont.....	62,600	216,000,000
Total.....	323,000	1,278,000,000

The remaining 2,117,000,000 kilowatt hours required in the next six years must be developed by steam and storage hydraulic developments. On the latter we can not definitely estimate now.

This means that with the industrial growth of New England the output of the commercially feasible water powers will be quickly absorbed and that steam generated electric power will supply the greater part of the increased demand. It would appear that the industrial growth is at the rate of 15 per cent per annum so far as it affects the electric light and power companies. With this rate of growth, the hydroelectric power added will be quickly absorbed up to about 350,000 kilowatts, and the balance of about 1,100,000 kilowatts, which is estimated to be needed by 1924, will have to be supplied by steam.

This supply should be furnished by large steam stations, one located approximately between Bridgeport and New Haven, and one on the northeast shore of Massachusetts each of 300,000 kilowatts. Additions should be made at the proper time to the following stations:

	Kilowatts.
Boston	60,000
Providence	60,000
New Bedford	75,000
Norwich	70,000
Chicopee (Turners Falls Power Co.)	75,000
Total	340,000

This program will provide about 1,000,000 kilowatts from 1919-1924, inclusive.

In order to utilize this properly, carefully selected interconnections should be arranged. These will probably be provided slowly as the business of the various companies grows.

At the present time the laws of Maine prohibit the exportation of electric power to other States. Maine contains the largest percentage of the available water power and if it is deemed necessary to make use of this for the general good of the industries in New England, legislation will be necessary. Similarly in New Hampshire the consent of the public utility commission must be secured so that power may be transmitted outside of the State.

Water power should be developed for the conservation of all the coal that can economically be saved, and at the same time large steam stations should be built so that inefficient plants may be curtailed, and gradually discontinued.

The locations of the transmission lines will depend much on the individual developments.

Accurate records of the coal consumption in New England show that 1,606,226 tons (short) were used to produce 1,283,550,000 kilowatt-hours. Six hundred and eighty-five million kilowatt-hours were produced by 685,999 tons or at the rate of 2 pounds per kilowatt-hour. The balance, 598,154,000 kilowatt-hours required 921,226 tons or at the average rate of 3.04 pounds per kilowatt-hour. If the total kilowatt-hours 1,283,550,000 could be generated at 1.8 pounds of coal in efficient power plants there would be a saving of 445,000 tons, which at the present average price of coal in New England, cost above \$1,600,000. Most of this might be saved.

NEW YORK.

New York City with its five boroughs, separated by rivers into three parts, has advanced considerably in centralization and in conservation of fuel. Its interconnected plants at Thirty-ninth Street and Two hundred and first Street, Manhattan, form the main supply for the Boroughs of Manhattan, The Bronx, and Queens.

The Pearl Street and Gold Street plants of the Brooklyn company serve Brooklyn and are interconnected for a moderate capacity with the Manhattan plant at Thirty-ninth Street. The Borough of Richmond has a plant of its own, unconnected with the others and until late years of low economy.

In the face of a doubled fuel cost the demands of Greater New York and the economic growth of the system of electric generation and supply can not fail to follow lines of markedly increased centralization. This will result in a great decrease of individual plants, a greatly increased demand on central stations, and a high efficiency of production. The present high rate of coal consumption—2.3 pounds per kilowatt-hour—is due in part to the difficulty of obtaining fuel of the quality formerly obtained. When such fuel has been received the consumption was under 2 pounds. This difficulty has been experienced by nearly all the central power plants from which data has been received.

It does not appear at present that New York can obtain any benefit from hydraulic developments. Those of New England will be insufficient to supply local demands. The supply from a development on the Delaware could be completely absorbed by New Jersey and Philadelphia. New York could, however, furnish power for the adjacent towns of New Jersey, as was proposed during the war, and can supply power to western Connecticut, as it is at present doing to a certain extent to the New York, New Haven & Hartford Railroad.

BALTIMORE.

At Baltimore improvements may be looked for in increased production from enlarged economic steam stations, but greater economy will be obtained from the Holtwood plant of the Pennsylvania Water & Power Co. on the Susquehanna River. Improvements and additions to this plant will aid in cutting down the use of coal at Baltimore. It is probable that an interchange arrangement through frequency changers with the suggested plant at Conowingo would also produce a further supply of hydroelectric power and connect Baltimore to the great interconnected water and fuel system proposed for Philadelphia and adjacent industrial area.

NEW JERSEY AND PENNSYLVANIA.

The State of New Jersey and the cities of Philadelphia and Wilmington are given in the table on page 104 as a nucleus of power centralization plan which would include the anthracite coal mining and steel industries of the contiguous section of eastern Pennsylvania. The total kilowatt-hours given in this table (1,515,944,000) are only a minor part of the power consumption and future demand of this great industrial area.

The fuel economy shown is poor, 2.566 pound per kilowatt-hour, and could be improved, by centralization and interconnection, to at

least 1.8 pounds of coal, which alone would result in a saving of 580,000 tons of coal per year, which at \$5 a ton amounts to \$2,900,000. To this could be added the economies due to improved plants in the coal region, with a probable supply of cheaper fuel, and to their interconnection with the main system.

The main economy that could be obtained appears to be in the utilization of the water powers of the Delaware and Susquehanna Rivers which lie in the northern and southern parts of the industrial section.

The Delaware River project contemplates the complete development of the Delaware River from its headwaters in Delaware County, N. Y., to a point below the Delaware Water Gap in Pennsylvania.

The project consists of two parts:

1. The development of storage reservoirs.
2. The development of power sites.

There are six reservoir sites available, and the stored water from these plus the natural stream flow would be used through 10 power stations, having for 9 of these a total head of 527 feet and a 400 feet head for the remaining station, operated from Mongaup Reservoir.

TABLE No. 6.

Power house No.	Fall (feet).	Second-feet.	Heights of dams above low water.	Length of canal (miles).	Brake horsepower on basis 80 per cent efficiency (12 hours).	Machines installed (horse-power).
1.....	40	5,230	20	2½	19,000	21,600
2.....	85	5,700	20	5½	40,100	64,800
3.....	100	6,668	75	3	60,500	62,300
4.....	85	7,460	47	3½	57,500	61,000
5.....	40	7,850	106	5	24,000	36,000
6.....	40	7,500	40	0	27,800	33,700
7.....	30	7,620	20	2	20,800	25,100
8.....	42	7,720	28	2½	28,500	35,500
9.....	38	7,800	10	5	20,000	23,200
10.....	67	8,070	45	2½	40,000	57,600
Total.....	927		446	32½	361,400	432,300

The power developed, 361,400, allows us to deliver to the consumers over 300,000 horsepower and there will be installed 432,300 horsepower of apparatus.

This shows that 300,000 horsepower, or 225,000 kilowatts, can be developed giving, at 50 per cent load factor, about 1,000,000,000 kilowatt-hours. If these were delivered to the New Jersey and Pennsylvania systems, which now use on the average 2.54 pounds of coal per kilowatt hour, there would be saved 1,270,000 tons, which, at \$5 per ton, the present price, would represent \$6,350,000.

Further economies could be made in the larger steam plants still operating on these systems, so that an even better showing might be made. The estimated present cost of the proposed water power project is approximately \$45,000,000. The estimated overhead costs on this would be, at 12 per cent, \$5,200,000, thus leaving a considerable margin between the savings in coal and the fixed charges on the proposed system.

The proposed Susquehanna River project at Conowingo is about 10 miles below the Holtwood plant of the Pennsylvania Water &

Power Co. It is between 40 and 50 miles from Chester, Pa., and between 30 and 40 miles from Wilmington. If this were developed and interconnected with the Wilmington and Chester systems a substantial saving in coal would be obtained.

An investigation shows that this project can be developed for 110,000 kilowatts and at 62 per cent load factor will generate 600,000,000 kilowatt-hours. The daily output will vary from 350,000 to 2,640,000 kilowatt-hours. This power should be used on the New Jersey-Pennsylvania system.

The approximate output and peak loads for 1917 of the plants in the New Jersey-Pennsylvania system are as follows:

Plant.	Maximum load.	Load factor.	Kilowatt hours.
	<i>Kilowatt.</i>	<i>Per cent.</i>	
Public service (northern and central New Jersey).....	152,000	46	735,000,000
Philadelphia electric.....	150,000	46	601,000,000
Lehigh district.....	48,000	72	298,000,000
Southern New Jersey.....	30,000	57	150,000,000
1917, total loads.....	410,000	50	1,784,000,000

In 1920 it is estimated the kilowatt hours on these systems will be 2,250,000,000 and the maximum load 520,000 kilowatts. The annual load factor will be about 50 per cent.

It has been ascertained that in the steam plants of the systems noted in the tables coal is consumed at the rate of 2.54 pounds per kilowatt hour. Thus 600,000,000 kilowatt hours of hydroelectric energy can be secured at Conowingo with a saving of 762,000 tons of coal per year, which, at \$5 per ton, the present average price, is \$3,810,000. This saving can be readily secured and at the same time further economies made in the operation of the other plants of the interconnected companies and systems.

The steam-generated kilowatt hour output of the New Jersey, Philadelphia, and Wilmington plants for 1918 was 1,515,944,000. If the New Jersey and Pennsylvania systems were thoroughly interconnected so that the Delaware and susquehanna hydroelectric developments could be completely utilized, they would furnish 1,600,000,000 kilowatt hours total and entirely replace the steam-generated power. Further, this hydroelectric energy could be made to apply to industrial or other plants which now operate under very inefficient coal conditions. Undoubtedly the amount generated by these individual plants far exceeds the kilowatt hours available from the hydroelectric projects on the two rivers noted. So that there appears to be an excellent field for the absorption of the total energy of these water powers, either for the replacement of coal in the public utility systems or in factories and other establishments generating power by wasteful and inefficient methods.

In order to carry out this plan successfully it is necessary to electrically interconnect New Jersey north and south, Philadelphia, Pa., Bethlehem, Pa., Wilmington, Del., and the power stations at Hauto and Harwood, Pa. Under these conditions the water power can be used to best advantage and the transportation of a large tonnage of coal avoided.

SOUTHERN STATES POWER CONDITION.

In the States of Alabama, Georgia, Tennessee, North Carolina, and South Carolina in 1917 the total generating capacity for electric power in the plants of the principal public utility companies was 662,127 kilowatts, 197,331 kilowatts being steam apparatus and 464,796 kilowatts being water-driven generators.

These produced about 90 per cent of all the electrical power generated in these States.

The water-power plants will furnish about 8 per cent and the steam plants 11 per cent of all the energy output during the next few years. In 1917 they produced 1,893,400,000 and in 1918, 2,090,400,000 kilowatt hours. It is anticipated that by 1924 the demands on these main systems will be such that 1,000,000,000 kilowatt hours more will be needed to supply the industrial needs. To accomplish this the following installations are recommended: A hydroelectric plant of 150,000 kilowatts and a storage reservoir on the Tallapoosa River at Cherokee Falls, Ala.; three stations on the Georgia Railway & Power Co.'s system totaling 100,000 kilowatts and a plant on the Columbus Power Co.'s system in Georgia; and a development of 15,000 kilowatts on the Ocoee River at No. 3 site, with another generator of 9,375-kilowatt capacity in the Great Falls Power Plant, Tennessee. The developments in the last two States would obviate the need of coal for power purposes. The annual coal consumption on the Alabama Power Co.'s system in 1924, when delivering a largely increased load, would be about 210,000 tons. The present consumption is about 115,000 tons.

The power for these Southern States has largely been developed through the installation of generating apparatus on the waterfalls of the rivers and the coal consumption has been relatively small. The hydroelectric installations constitute about 70 per cent of the total capacity, and the output is even higher than this percentage.

If the recommendations of this report are followed only about 200,000 tons of coal may be used on these large systems in 1924, even after the energy output has been increased by 50 per cent over the 1918 output. The Southern States are in a particularly fortunate position in that there are many water powers still unutilized which can be readily developed and connected to the general electrical high-tension network and used to replace what coal is still employed, and also to supply power for the supplanting of coal in any industrial operations where electricity can as readily be employed.

All the systems should proceed to interconnect electrically to take advantage of the diversity which obtains on their systems and thus avoid further unnecessary capital investment.

Separated systems.

State and system.	Prime power average year.			Prime power dry year.		
	Hydro.	Steam.	Total.	Hydro.	Steam.	Total.
Alabama.....	275,000,000	110,000,000	385,000,000	242,000,000	143,000,000	385,000,000
Georgia systems.....	500,000,000	.....	500,000,000	370,000,000	130,000,000	500,000,000
Tennessee system.....	373,000,000	12,000,000	385,000,000	345,000,000	40,000,000	385,000,000
Total.....	1,148,000,000	122,000,000	1,270,000,000	957,000,000	313,000,000	1,270,000,000

Separated systems—Continued.

ALL SYSTEMS INTERCONNECTED.

State and system.	Prime power average year.			Prime power dry year.		
	Hydro.	Steam.	Total.	Hydro.	Steam.	Total.
Alabama, Georgia, Tennessee.....	1,238,000,000	132,000,000	1,370,000,000	1,040,000,000	330,000,000	1,370,000,000
Increase or decrease by interconnection..	90,000,000	10,000,000	100,000,000	82,000,000	17,000,000	100,000,000

Kilowatt-hour increases.

	Average year.			Dry year.		
	Hydro.	Steam.	Total.	Hydro.	Steam.	Total.
Present system inter-connected.....	1,238,000,000	132,000,000	1,370,000,000	1,040,000,000	330,000,000	1,370,000,000
Tallapoosa development will bring the output up to (150,000 kilowatts).....	1,946,000,000	154,000,000	2,100,000,000	1,490,000,000	610,000,000	2,100,000,000
Bartlett's Ferry development will bring the output up to (28,000 kilowatts).....	2,120,000,000	110,000,000	2,230,000,000	.....	.....	.....
Mathis-Tallulah development on the Tallulah River and the Tugaloo development will bring the output up to....	2,336,000,000	164,000,000	2,500,000,000	.....	.....	.....

PACIFIC COAST.

A study of the electric-power conditions on the Pacific coast shows primarily the need for the further development of hydroelectric power to replace that now generated by fuel oil and to meet the rapidly growing demands for electric energy in industrial lines.

The price of fuel oil has risen from 70 cents to \$1.60 per barrel since 1915, and the production from the southern California oil fields has not increased greatly, so that it is necessary to conserve fuel oil, and the most economical method of accomplishing this is to develop hydroelectric power. The use of coal is not feasible except in a few isolated places and under exceptional conditions. Owing to the water shortage on the hydroelectric-power systems in 1918, it was necessary to consume on these systems approximately 2,000,000 more barrels of oil than in 1917. At the average price of \$1.55 this would represent \$3,100,000.

Already hydroelectric developments are under way to meet the two above-mentioned needs, and there are many others that are known and will be developed as the commercial and economical needs are made apparent.

All the steam power can not be replaced successfully, as the steam stations are necessary for regulatory and control operations, as well as for serving the system with power in the event that a breakdown occurs in the hydroelectric portion of the system.

The States of Washington, Oregon, and California have about 43 per cent of all the available undeveloped water power in the United

States, but the power market in many places must be developed to utilize this ample supply of hydro power. Power can be and is transmitted many miles, but there is an economic limit to the distance to which it can be transmitted.

Much oil is used in manufacturing establishments for power generation. Many of these can be operated by central electric power. The amount of oil in such operations can not be rigidly set down, but it is millions of barrels.

The railroads use many millions of barrels, much of which might be saved by operating certain portions of these lines by electricity.

The Southern California Edison Co. through its new hydroelectric developments, turning out 300,000,000 kilowatt-hours per annum, will save about 1,500,000 barrels of oil per year.

The San Joaquin Light & Power Corporation is putting in hydroelectric developments which will go far in saving about 300,000 barrels of oil per year.

The Pacific Gas & Electric Co., Great Western Power Co., and Sierra & San Francisco Power Co. consumed over 2,000,000 barrels in 1918, an increase of 700,000 over 1917.

The approximate total of the consumption of oil by 10 companies in California in 1918 was 4,000,000 barrels, at a cost of \$6,200,000. This oil would represent 800,000,000 kilowatt-hours. Hydroelectric developments are now going forward which will develop in four years 1,500,000,000 kilowatt-hours, so that there is being provided ample power for the anticipated industrial growth and the replacement of as much steam-generated power as safety warrants. For table showing present and proposed capacities of power companies in California see page 86.

It is obvious there are several other districts not mentioned or considered where the same theory would apply or has been applied. In Chicago, Detroit, and Cincinnati great economic stations already exist, and the centralization plan is being applied in these and other large cities to their individual problems. Keokuk, St. Louis, and points between along the Mississippi River are already connected. Much can still be done at Minneapolis and St. Paul. Water power from the Adirondacks and the St. Lawrence, if necessary, can be brought south to northern New England and the region around the upper Hudson to supply Schenectady, Albany, and Utica. It is possible by this plan to create a relay system from the water power of Niagara to that of the Maine lakes, so supplying power over a wide belt of productive territory.

ELECTRIFICATION OF RAILROADS.

A national plan for the production of cheap power and for fuel conservation as described must include in due time the electrification of many railroads. This is a problem by itself, and can only be alluded to here, as the data must be obtained by a special and extensive study. It has been estimated that from 120,000,000 to 140,000,000 tons of coal are used for railway purposes, and that electrification would go far toward the relief of the railroad situation. If all the railways of the country were completely electrified—an impossibility, of course—the saving in coal by central power plant generation has been estimated at from 85,000,000 to 100,000,000 tons a year, or about one-sixth of our total coal production.

LIMITED SUPPLY OF WATER POWER.

The foregoing discussion shows that the water powers developed or profitable to develop in New England and Pennsylvania, and in fact in all of the northern and eastern industrial sections will supply only a portion of the present requirements and that we must rely on fuel for the major part of our immediate supply of power and all of our future demand.

This is the most important development of the studies made by the power section.

The detailed description of, and the engineering recommendations for each section are only of value in suggesting lines of progress for each project. Much careful study will be required before final choice can be made and construction begun. The main conclusion is that the popular idea that our own water power resources are ample for our needs is fallacious and that the time has come when we must not only use all hydro resources profitably, but also begin at once to readjust ourselves to the necessity of using our fuel resources far more effectively than we have in the past if we are to produce our raw material and manufacture our products at the lowest cost.

This country fortunately has ample supplies of fuel, the problem of its doubled cost means that to get economy equivalent to that existing before the war we must increase the production of each individual workman by power, and produce the power at a less cost so that the gain for both, added together, equals the present increase in the cost of fuel.

It might be assumed after reading the above summary of the tendency toward centralization, that the problem of cheap power generation and fuel conservation would solve itself by the process of natural business development. The quick intelligence and resourcefulness already displayed by the engineers and mechanics of the country would assure this were the power industry free to adjust itself to changing conditions by the usual method of other productive industries, those of bargain and sale. But the industry is not free and this directs attention to the laws which govern capitalization, combination, competition, maximum rate of earnings or reward, and other factors affecting the attraction of capital toward this kind of industrial investment.

(5) NOTES ON THE EFFECT OF THE PRESENT NATIONAL AND STATE LAWS RELATING TO CENTRALIZATION; RATE REGULATION, AND NATURAL RESOURCES, WITH A SUGGESTION OF THE NECESSITY FOR PROVIDING AN INCENTIVE FOR SAVING COAL AND PRODUCING POWER.

There are certain laws now on the statute books controlling combinations of public utility companies tending toward monopoly, regulating rates, and restricting territorially and otherwise the free use of power resources, particularly in the case of projects on public lands or occupying public land with any portion of the system.

If a centralization plan is to be worked out it will inevitably discontinue smaller plants, their business being taken over by the larger stations. In nearly any section such action would involve plants in several States. The question at once arises is such a plan in opposition to the Sherman Antitrust Act. It may be that, if done with the

consent of all concerned, in strict accordance with the laws and the rulings of regulatory commissions and with no intent to restrain trade, this would be a proper extension of the operation of a natural monopoly. Inquiry along these lines, shows that such a theory has not been established as a settled point of law, and that some doubt exists in regard to it.

Safety of the investment is the first requirement of capital and any doubt of the validity of a plan must be removed before it can succeed.

The maintenance of the value of an investment requires certain earnings in addition to those necessary for its preservation or replacement. The laws regulating the rates to be charged by public utility companies and which control their earnings do not permit these rates to be increased except by methods already described, these methods depending on the rules of procedure laid down by the commissions in the several States. Methods of increasing rates vary materially and in many cases are not quickly adaptable to the changing conditions of the coal, labor, and material market, nor were they designed to meet the emergencies created by the war.

It is obvious, therefore, that rates can not be raised in anticipation of the necessity of so doing, but the event must be awaited, and the effect of increased costs of manufacture actually developed. This inability to promptly raise the rates for the sale of energy to meet the sudden and great increase in cost in 1917 and 1918 had a considerable part in reducing the net revenues of power companies and seriously impaired their credit.

The necessity for laws regulating public utilities has been demonstrated and their effect has been to settle many disputed questions for the general good. Since the creation early in this century of these laws and the commissions which administer them, principles of valuation and capitalization both of tangible and intangible assets have been established, and these have tended to standardize and strengthen the industry. It has further been settled that the best development of the industry is not promoted by competition, and this method is now rarely used as a stimulus. The business has really become a legal monopoly within the area of each individual project. The tremendous growth of the industry, particularly in great cities and industrial districts has required the investment of earnings to provide for additional growth, and in this way is adding to assets so that, with the regulation of capitalization and valuation, it may be said that the speculative period of the industry is past, and that it has become one of the fundamental and necessary elements of the life and progress of the country. To accomplish its function of supplying power at a low price to the nation, the power business should be put on such a safe investment basis that it can attract the necessary capital at low rates, for the cost of money is as much a part of the cost of the plant as the steel in its buildings.

During the war the bankers' charge for supplying money to public utilities was prohibitive. The sum of the annual interest and amortization charges was more than could be earned in the business. How long this condition will prevail can not be surmised, but part of the high cost of money to the industry was due to the uncertainty of its earnings. The industry was unable to meet the changed conditions of war and those existing thereafter except by increasing

rates, which might be reviewed, suspended, or reduced at some later date.

The rate of return permitted varies from 6 to 8 per cent over prescribed charges, and this can not be exceeded to any material extent for any length of time.

The industry, therefore, can not offer such special inducements as are necessary to start and maintain the great movement of expansion and centralization required to meet the demand for cheap power and to overcome the increased costs of plant and operation.

A tendency is now developing which restricts the application of hydraulic resources to certain territory or to public purposes only. Instances of this are the laws of the State of Maine, requiring that hydraulic power hereafter developed in that State must be used within its borders and not exported. The State of New Hampshire has a similar regulation, except that permission to export may be obtained from the public service commission.

The legislative authorization for the development of the water-power project at Muscle Shoals, in Tennessee, by the National Government carries with it the prohibition of the sale of power for resale or for commercial purposes. In consequence, it can not be employed for general use or for the relief of a commercial power shortage. A similar restriction limits the use of power developed by the city of Los Angeles.

The utter loss of economy in power supply caused by such laws is obvious. Maine has power far beyond that necessary to supply such industries as it can attract in a great many years, but in the meanwhile the rest of New England is compelled to use high-priced fuel, although anxious to absorb all the hydro power it can obtain. The restrictions at Muscle Shoals and Los Angeles deprive the enterprises of their best customers, wasting fuel and unsettling the business by fear of Government or municipal competition. The theory of competition in the power business has been condemned and generally prohibited by all State utility commissions, but apparently it is here revived for the benefit of public enterprises. A confusing and discouraging condition tending to retard power developments thus arises in certain districts.

The effect of these restrictions does not mean that the industry will stop growing or that great economical systems of limited area will not continue to grow, but it does mean that no general incentive or encouragement is offered under the present laws and conditions to develop comprehensive groups of power systems covering the principal industrial areas, with the object of producing cheap power and saving fuel. The incentive that is lacking is an increasing reward to the power industry for the increasing cost of production of power for use in general industry. The enterprise now engaged in producing electric power in any district for public purposes is restricted to specific prices for that power, and dependent on a return on its investment which is established to be reasonable. The enterprise may expand and earn its return on a larger investment, but if it can cheapen its product by any means and lower its rates, it can not have a share of this saving in the form of an increased rate of return. In other words, it can not have as a reward a part of the profits it would create for others by

cheapening its product. Under these circumstances it can not be expected that the rapid development required to meet the present situation will take place, for a business allowed to earn only a fixed return will take only the safest and most conservative path in its expansion. A business can afford to invest money only when it can get it cheaply, and can utilize it to the utmost, and show that a gain can be made by its use.

There should be a mutual interest and partnership between the power industry and its customers, so that when a company producing power can by its efforts reduce the cost a fair proportion of this saving will accrue to it as a reward and the remaining portion, in the form of reduced rates, enable the consumer to manufacture his product at less cost. Such an incentive can be provided with the necessary regulatory control, and has been done with benefit to all in England, in Massachusetts, and Texas in connection with certain public utilities. The object to be attained should be cooperation and a fair share of the profit to each interest. The method by which this can be done, whether by sliding scale or some other form of division of profits, must be left to careful study of experts. The important point to establish here is that some such procedure is necessary and possible.

There is another difficulty which has operated to prevent an active development campaign, and that is the nature of the laws and regulations of the Government in regard to hydroelectric development on public lands and forest reserves. In spite of these restrictions developments have occurred in the past, but during recent years and pending the adoption of suitable water-power legislation all new work has been at a standstill. New and well-conceived legislation removing these objections would greatly stimulate projects in the West, where many proposed installations would be carried to completion.

(6) THE EFFECT OF CHEAP POWER ON PRODUCTION AND WAGES IN THIS COUNTRY AND THE NECESSITY FOR IT IN OBTAINING WORLD TRADE.

The war has taught us very forcibly the stern necessity and duty of saving our fuel resources and that it is almost criminal to continue the present waste, examples of which have been given in these pages.

The war has further left us with a general and heavy increase in wages to both skilled and unskilled labor. It is true that our usual inflow of additional labor was stopped by the war four years ago; that an abnormal outflow of labor is occurring, due to aliens returning to their homes after the war; that our own armies have absorbed a considerable portion of our normal working forces, and that it will take several years before this condition is readjusted.

It is estimated from these facts that our present labor supply is about 12½ to 15 per cent below normal.

For these reasons and the further reason that most of our voting citizens are workers, it is reasonable to assume that wages will be maintained on a higher scale than before the war.

It is unnecessary here to describe the circle of high wages and high costs of living, but it is necessary if high wage conditions are

to continue that the money for these wages be provided and earned. When a man's wages exceed what he can earn by his own unaided efforts, the only way he can continue to be paid such wages is by giving him such assistance that he can do correspondingly more work or turn out proportionately more product. Assuming the necessary skill, this can only be done by mechanical means, which in turn requires power. To earn high wages, therefore, a man's own efforts must be multiplied by aids operated by his own strength and skill or by power from outside sources.

The general trend of advance in new business in this country is toward foreign trade and a world market for our products. If so, we are brought into competition with foreign labor, which has always received a lower wage than our own.

If we do not wish to and can not reduce our own wages to meet such competition, then we must meet it by cheaper raw materials, greater mechanical ingenuity and efficiency, and great productiveness. All of these depend on power, so that an ample and cheap supply of power at the hand of the producer and the manufacturer will give him one great element of success in competition for world trade, enable him to meet with less difficulty the requirements of high wages, and promote the content and peaceful progress of the country.

It is believed that the method suggested here of stimulating the power industry to centralization and the utilization of our water powers by providing under Government regulation the necessary incentive to capital would go far toward solving the problem.

Government ownership is not necessary or advisable, for it would never possess the required initiative and enterprise, nor would the incentive toward continued progress and improvement be present.

To recapitulate briefly, we are confronted with the demand for high wages, which can only be paid by a high rate of production and an increased individual output.

The only way these can be had is by a cheap and ample power supply. We are met with new difficulties in our effort to obtain this power. In the northern and eastern section of the country we find that our feasible water developments amount to only a small part of the necessary power supply, that fuel must be used for most of the present supply, and after this water has been utilized for all power required by the never-ceasing and insatiable demand.

We find that the cost of fuel has doubled, which makes the individual production of power more wasteful than ever and that economy demands the production of power by great interconnected systems of superpower plants.

The creation and operation of such plants to supply all demands for power, traction, light, and heat implies a development in size of system and area of distribution which takes them from the class of intrastate industry to that of interstate commerce in the transmission of power. They substitute for the transport of the actual coal by rail the transmission of its energy through wires or cables. An industry of this character and economic value becomes of national rather than local importance, and should be treated and encouraged as such on the broad lines of a comprehensive policy equitable alike for the country and for the industry. Such a farsighted policy would develop the industry's full worth as a great national asset.

Since the beginning of the war special studies of the conservation of fuel, of the use of water powers, and of the production of power have been made by the Department of the Interior, Department of Commerce, the Fuel Administration, the War Industries Board, the Ordnance Department, the Chief of Engineers of the Army, and others. These efforts should not be allowed to cease or their records to be scattered, and it is most earnestly recommended that an agency be established by Congress to study and report on the conservation and use of our natural resources in fuel and power with a view to the supply of power for all purposes in this country, and specifically directed to inform the Congress on the methods best adapted to encourage the cheapest production and use of power in the various main industrial sections of the United States.

It is almost unnecessary to state that such a board should be composed of representatives of the highest administrative and technical ability and experiences from the Government departments, technical professions, and industries concerned.

If it is necessary to strengthen this recommendation and prove it is timely and profitable by the example of others, reference is made to a final report made by the coal conservation committee of the ministry of reconstruction to the British Parliament dated January 23, 1918, which treats of the conservation of fuel and the production of cheap electrical power. It recommends a great interconnected system of superpower plants, using the cheapest fuel most economically to distribute electric power over all England. Such a supply has not previously been available in England. We are on notice, therefore, that we may be forced to compete in the future with an industrial England, increasing its individual output by power cheaper than that formerly at hand and with a wage scale less than our own. This means finished product at a low cost.

CHARLES F. LACOMBE,
Major, Engineers, United States Army.

Collaborating on Part 6:

GEORGE F. SEVER,
Major, Engineers, United States Army.

EXHIBIT A.

DECEMBER 28, 1917.

MY DEAR MR. WILLARD: I have just received your letter of December 27 with regard to the shortage of power for manufacturing plants in certain enumerated districts.

I have notified the Chief of Ordnance, the Chief of Engineers, the Chief of the Signal Corps, and the Quartermaster General of the contents of your letter and requested them to comply with the recommendation.

Very truly, yours,

NEWTON D. BAKER,
Secretary of War.

HON. DANIEL WILLARD,
Chairman War Industries Board, Washington, D. C.

WAR INDUSTRIES BOARD,
COUNCIL OF NATIONAL DEFENSE,
Washington, December 27, 1917.

MY DEAR MR. SECRETARY: I am advised by Judge Parker, chairman of the priorities committee, that there is a shortage of power for manufacturing plants in the following districts:

Philadelphia, Pa.
Wilmington, Del.
Baltimore, Md.
Newark, N. J.
Claremont, N. H.
Worcester, Mass.
Rock Island, Ill.
Davenport, Iowa.
Dayton, Ohio.

District comprising Massillon, Ohio; Canton, Ohio.

Because of this shortage in the districts mentioned it is recommended that instructions be given to the purchasing bureaus of the War Department similar to those already issued with reference to Niagara Falls and Pittsburgh; that is to say, that no additional orders be placed in the regions referred to save on the approval of the War Industries Board after an investigation.

I trust this recommendation will meet with your approval.

Very truly, yours,

D. WILLARD, *Chairman.*

HON. NEWTON D. BAKER,
Secretary of War, Washington, D. C.

WAR DEPARTMENT,
Washington, December 11, 1917.

MR. DANIEL WILLARD,
Chairman War Industries Board, Washington, D. C.

SIR: In accordance with your request of December 7, 1917, I have instructed the purchasing bureaus of the War Department to place no further war orders in the Niagara Falls and Pittsburgh districts, except with the approval of the War Industries Board after an investigation as to the power supply necessary for the fulfillment of the contracts.

Respectfully,

NEWTON D. BAKER,
Secretary of War.

EXHIBIT B.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF STAFF,
DIVISION OF PURCHASE AND SUPPLIES,
Washington, March 25, 1918.

Memorandum for: The Adjutant General of the Army.

Subject: Placing of orders in districts where a shortage in electric power exists.

1. The Secretary of War directs that a circular letter be sent to each
 - The Acting Quartermaster General,
 - The Acting Chief of Ordnance,
 - The Chief of Engineers,
 - The Chief Signal Officer, and
 - The Surgeon General,

in effect as follows:

"There exists a shortage of electric power for manufacturing purposes in the following districts:

"Niagara Falls, N. Y.

"Pittsburgh, Pa.

"Philadelphia, Pa.

"Wilmington, Del.

"Baltimore, Md.

"Newark, N. J.

"Claremont, N. H.

"Rock Island, Ill.

"Davenport, Iowa.

"Massillon, Ohio.

"Canton, Ohio.

"Camden-Burlington, N. J.

"Alliance, Ohio.

"Connellsville, Pa.

"No further orders shall be placed in any of the above-named districts the filling of which will involve the consumption of power by any industry in excess of that heretofore consumed by it, without first obtaining the approval of the War Industries Board, which will investigate and advise as to the availability of power supply for the fulfillment of such additional contracts.

"Applications to place further orders will be made direct to the Director of Purchases and Supplies for submission to the War Industries Board.

"These instructions will not, however, in anywise interfere with the making of purchases or the placing of orders or contracts which do not require the seller or manufacturer to increase his consumption of power.

"Previous instructions relative to this subject are rescinded."

BRIGADIER GENERAL, N. A.
DIRECTOR OF PURCHASES AND SUPPLIES.
ASSISTANT CHIEF OF STAFF.

EXHIBIT C.

65th Congress, 2d session, H. R. 12776.

In the House of Representatives, August 19, 1918.

Mr. Sims introduced the following bill; which was referred to the Committee on Interstate and Foreign Commerce and ordered to be printed:

A bill to provide further for the national security and defense and for the more effective prosecution of the war by furnishing means for the better utilization of the existing sources of electrical and mechanical power and for the development of new sources of such power, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That when used in this act, unless the context shall require a different interpretation—

(a) The term "power plant" means a plant equipped for, and employed or intended to be employed in, generating, developing, transmitting, or distributing electrical or mechanical power, and includes all machinery and appliances therein contained, together with all lines transmitting or distributing power in connection therewith, and all other property the ownership, use, or occupancy of which may be appropriate to or useful in connection with the maintenance and operation thereof.

(b) The term "private power plant" means a power plant owned or operated by any person, association, corporation, or body politic, other than the United

States, for the purpose of generating, developing, transmitting, or distributing such power, either for sale or for the use of the owner or operator thereof or of some other person.

(c) The word "person" includes natural persons, copartnerships, joint-stock companies, voluntary associations and corporations, and the receivers and other custodians of the property of any of them.

(d) The word "operator" means the owner, lessee, or other person in general control or operation of any plant, factory, or enterprise.

(e) The term "property" includes real and personal property of every nature and description, together with any right, interest, or easement therein or appurtenant thereto.

(f) The term "war material" means any material or commodity which, in the opinion of the President, it may at any time be necessary or important to produce or of which he may deem it necessary or important to increase the production.

(g) The term "to acquire" means to purchase, requisition, condemn, or take over the title to, or to lease, requisition, condemn, or take over the right to use, occupy, or operate the whole or any part of; and, unless it shall be limited by the context, includes all such acts.

(h) The term "within the boundaries of the United States" means all lands and waters subject for any purposes to the jurisdiction of the United States of America.

(i) The term "war period" means the time to elapse until six months after the President shall, by proclamation, have declared the war between the United States and the Imperial German Government and its allies to be at an end.

Unless it shall be otherwise specifically provided herein the inclusion of any matter or thing within the definition of any word or term by the foregoing provisions of this section shall not be deemed to exclude therefrom any other matter or thing which under the usual construction of such word or term would fall within the meaning thereof.

Whenever, by this act, any duty is imposed upon any person, it shall be deemed to be imposed as well upon all agents, servants, or officers of such person in so far as it shall be within the scope of their respective functions.

SEC. 2. That the President is hereby authorized and empowered, within the limits of the amounts herein authorized, or that may hereafter be authorized—

(1) To construct at any place or places within the boundaries of the United States such power plant or power plants as he may deem necessary, and in connection therewith to construct within such boundaries plants for the production of gas, coke, toluol, benzol, coal-tar products, and any other useful products that may be produced through or in connection with the coking of coal or lignite, or through or in connection with the combustion of any fuel.

(2) For the purpose of increasing the capacity or productivity of any private power plant within the boundaries of the United States to install in any such plant any structure, machinery, or appliances that he may deem useful to that end, either through agents or contractors employed by him, or by providing the owner or operator of such plant with funds to be applied to that purpose; to lease the machinery, appliances, and structures thus installed or any parts thereof to the owner or operator of such plant for a term of not to exceed the war period and such reasonable time thereafter as he may deem expedient in the interest of the United States, upon such terms as he may deem reasonable; and to enter into contracts requiring or permitting the lessee to purchase such appliances, machinery, and structures, or parts thereof, at or before the termination of such lease at their then value or upon such other terms as he may deem equitable for the protection of the interests of the United States and of the community served by such lessee. Whenever any such structures, machinery, or appliances shall have been installed and until the sale or other disposition thereof, the title thereto shall remain in the United States and shall be free and exempt from any liens, mortgages, judgments, or other encumbrances, whether created by act of the owner or operator of such plant or by operation of law. And upon and during any default in any payment of any sums due the United States under such lease or contract the President shall be empowered at all times to enter upon the premises upon which such machinery, structures, or appliances shall be installed and there to maintain and to operate them or any of them for the use of the United States free from any rent or other charge, or to take possession of and remove them or any of them from the premises.

(8) To aid in equipping any private power plant or in expanding any such plant to such extent as he may direct by making advances, upon such terms and conditions as he may determine, to the person operating or authorized to operate it, and in connection with such advances, to agree with such person that, if the actual reasonable cost of equipping or expanding such plant shall be in excess of its value at the termination of the war period, or at such later time not more than five years after the expiration of the war period, as he may deem reasonable for such valuation, and the machinery, structures, or appliances constituting such extension or expansion, or their equivalent, shall have been maintained and operated in accordance with his directions until such time, repayment of the whole or any part of such excess will be waived, and to provide by agreement for the manner of determining such costs and values by arbitration or otherwise and for the terms and time of such repayment: *Provided*, That the powers conferred by this subdivision shall be exercised only if the President shall deem that the emergency is such as to render it impracticable or undesirable to act with respect to such plant under any of the other powers conferred by this act.

(4) To acquire any private power plant within the boundaries of the United States.

(5) To construct any pipe or other transmission lines, or other structures, facilities, or appliances that he may deem necessary or useful for the purpose of better utilizing or of increasing the facilities of any power plant, or of combining the facilities or power of two or more such plants, or of better utilizing the gas, power, or products generated by them.

(6) To maintain, operate, and extend any plant, pipe or other transmission line, or other structure, facility, or appliance which he shall have constructed or acquired pursuant to the provisions of this act, and to deliver the power generated, and the products produced in any such plant to such persons and in such proportions and at such times and at such rates as he may deem proper.

(7) To require the operator of any private power plant within the boundaries of the United States to place at the disposal of the United States or to acquire from such operator, during the war period, the whole or any part of the power generated by such plant; and during such period to transmit or distribute, or to require such operator to transmit or distribute, such power to any other power plant or to any other persons for such periods, in such manner and quantities, and upon such terms as he may direct.

(8) To lease for the war period or for such period thereafter not exceeding five years, or for any shorter period and upon such terms as he may deem reasonable, to any person or body politic for use or operation by such person or body politic, any plant, transmission line, or other property or part thereof, constructed or acquired pursuant to the provisions of this act.

(9) In furtherance of any of the foregoing purposes, to modify, cancel, or suspend any existing or future contracts for the delivery of power to any person not engaged in the production of war material or to the extent to which he shall deem the power contracted for to be in excess of the requirements for the manufacture of war material by such persons or to which, in his opinion, it shall prevent the delivery of power which he shall deem necessary for the production of war material of greater or more immediate utility.

(10) In furtherance of any of the foregoing purposes, to acquire any property or property rights, including any public or private rights, or any interest in any such rights; or any material, machinery, appliances, or processes, patented or otherwise, which he may deem necessary or useful for the construction, development, expansion, or operation of any such plant or transmission lines.

(11) If in his judgment such action shall be necessary or useful for the purpose of this act to form one or more corporations under the laws of any State, Territory, District, or possession of the United States for the purchase, construction, extension, lease, maintenance, or operation of any such power plants or facilities, or for the merger or consolidation of any private power plants, or for the purchase of the whole or any part of the capital stock thereof or of the property thereof: *Provided*, That not less than the majority of the capital stock of any corporation thus formed shall be subscribed, and during the war period shall be retained by the United States, and that at no time shall it be a minority stockholder therein.

(12) To sell or exchange any plants or structures constructed by him and any property to which he shall have taken title, and any rights acquired by

him, whenever in his opinion the interests of the United States will be furthered by such sale: *Provided*, That no public right acquired by him shall be alienated for any term in excess of five years after the war period, upon any terms or conditions other than those prescribed by the sovereignty from which such public rights shall have been acquired: *Provided further*, That whenever in the opinion of the President any structure or appliance which he shall have installed in any private power plant or any structure or appliance in any such plant to which he shall have taken title, or any property or right which he shall have acquired from the owner of such plant, shall constitute an integral portion of such private plant, or shall be of such character that it would be uneconomical to separate it therefrom, the owner of such private power plant shall be accorded an option to purchase the same at the then reasonable value thereof to be ascertained either by agreement or by arbitration wherein the President shall select one arbitrator, the operator a second, and the two thus selected a third, before the same shall be otherwise offered for sale or exchange.

(13) To appoint and fix the compensation of such attorneys, engineers, draftsmen, clerks, and other employees as he may deem necessary for the execution of the powers herein conferred.

(14) To amend or modify any contract made by him pursuant to the provisions of this act so as to include therein any terms or conditions which it would have been lawful to include in such contract at the time of the making thereof.

SEC. 3. That the President may exercise the power and authority hereby vested in him and expend the moneys herein and hereafter appropriated, through such officers, agents, or agencies as he shall create or designate from time to time, may require any such officers, agents, or agencies to perform the duties which he shall impose upon them, and fix the reasonable compensation for the performance of such services. But no official or employee of the United States shall receive any additional compensation for such services except as is now permitted by law.

SEC. 4. That whenever any act done pursuant to the provisions of this act shall constitute a taking of private property within the meaning of the Constitution, just compensation shall be made therefor in an amount to be determined by the President; and if the amount so determined by the President is unsatisfactory to the person entitled to receive the same, such person shall be paid seventy-five per centum of the amount so determined by the President and shall be entitled to sue the United States to recover such further sum as, added to said seventy-five per centum, will make up such amount as will be just compensation therefor, in the manner provided for by section twenty-four, paragraph twenty, and section one hundred and forty-five of the Judicial Code.

SEC. 5. That the provisions of section three hundred and fifty-five of the Revised Statutes shall be inapplicable to the acquisition of real property under the provisions of this Act. Within three months after such acquisition a description of the property acquired and of the extent of the interest acquired therein shall be filed with the War Department and in the office in which, by the laws of the State, Territory, District, or possession wherein the property is situated, it is provided that instruments affecting the title to real property shall or may be recorded.

SEC. 6. That no structure affecting the navigable capacity of any navigable waters of the United States shall be constructed or installed under the provisions of this Act until the plans therefor have been approved by the Chief of Engineers and the Secretary of War.

SEC. 7. That any person who shall knowingly neglect or refuse to comply with any order or requisition made by the President or by any officer, agent, or agency whom he shall have designated or created pursuant to the provisions of section three hereof, or who shall knowingly obstruct or attempt to obstruct the enforcement of or the compliance with any such requisition or order, or who, by means of any false statement or fraudulent representation, shall induce or attempt to induce the President or any such officer, agent, or agency to lend, advance, or provide any moneys, or to provide or install any property, or to enter into any contract or to perform any other act authorized by the provisions of this Act shall be punished by a fine of not more than \$5,000 or by imprisonment for not more than two years, or by both such fine and imprisonment.

SEC. 8. That the President may retain any property and operate any plants, transmission lines, structures, facilities, or appliances constructed or acquired

under the provisions of this act for such time as he may deem necessary or advisable for the purpose of selling or otherwise disposing thereof.

If, at the termination of the period provided by the contract relating thereto, or of such extension of the time of payment therein provided for as in furtherance of the interests of the United States, the President may deem it expedient to grant, the owner of any plant or transmission line in or upon which any machinery, appliances, or structures shall have been installed pursuant to the provisions of subdivisions two and three of section two hereof, shall have failed to pay to the United States the value of such installations and all rentals or other return due for the use thereof, or shall have failed to provide for the payment thereof upon terms satisfactory to him, or shall thereafter default in such payments, the President may acquire title to such power plant and may thereafter sell it or maintain and operate it for such time as he may deem necessary for the purpose of protecting the interests of the United States.

Except as is herein otherwise provided all other authority granted to the President by the provisions of this act shall cease at the termination of the war period, but the termination of such authority shall not affect any contract executed, act done, or any suit or proceeding had or commenced under the terms of this act prior to the date thereof; and any offense committed or liability incurred prior thereto may be prosecuted in the same manner and with the same effect and shall be subject to the same penalties as if such authority had not terminated. Nor shall the termination of such authority prevent the collection of any moneys due the United States, or the sale or other disposition of any property which it shall have constructed or acquired pursuant to the provisions of this act.

SEC. 9. That all administrative expenses incurred in the exercise of the powers herein conferred shall be allowed and paid on the presentation of itemized vouchers therefor; and in order to defray such expenses there is hereby appropriated the sum of \$150,000, out of any moneys in the Treasury not otherwise appropriated, to be paid out upon warrants drawn on the Secretary of the Treasury by the President or by any officer, agent, or agency whom he shall have designated or created pursuant to the provisions of section three hereof.

For the purpose of construction, acquisition, maintenance, and operation of plants, transmission lines, and other material and property which the President is hereby empowered by the provisions of this act to construct or acquire and of providing funds pursuant to the provisions of subdivisions two and three, of section two hereof, there is hereby appropriated, out of any moneys in the Treasury not otherwise appropriated, the sum of \$200,000,000.

All revenues derived from the sale of any product of any plant or property, which shall have been constructed or acquired pursuant to the provisions of this act, or from the lease or operation of any such plant, property, or transmission line shall be available for the maintenance and operation of such plant, property, or transmission line; and all revenue in excess of the expense of such maintenance and operation and all sums received upon the sale of any property constructed or acquired pursuant to the provisions of this act or in repayment of any funds expended or provided pursuant to the provisions of subdivisions two and three, of section two hereof, shall be deposited and covered into the Treasury to the credit of this appropriation.

SEC. 10. That as soon as practicable after the first of January in each year the President shall cause to be submitted to the Congress a detailed report of all property constructed, acquired, or installed; of all moneys loaned or advanced, and all receipts and expenditures made pursuant to the powers conferred by this act.

SEC. 11. That this act may be cited as the "Emergency Power Act."

SEC. 12. That if any section or provision of this act shall be invalid for any reason whatsoever, the invalidity of such section or provision shall not be construed to affect the validity of any other section or provision thereof.

APPENDIX B

Report on Power Service for Western Pennsylvania and Eastern Ohio Districts

By

CAPT. LYLE A. WHITSIT, Engineers, U. S. Army
MR. FREDERICK DARLINGTON, Consulting
July 26, 1919



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REPORT ON POWER SERVICE FOR WESTERN PENNSYLVANIA AND EASTERN OHIO DISTRICTS.

PREFACE.

PURPOSE.

The following report is a description of the present electrical power resources and requirements in the district of western Pennsylvania, including Pittsburgh, Butler, and Wheeling, W. Va., and eastern Ohio, including Youngstown, Warren, Canton, Akron, Cleveland, and intermediate sections. Power resources are required here to supply the largest and most congested industrial district of the United States. The report will indicate the annual growth of the electric power generated each year from 1913 to date and the maximum instantaneous power demand on the central stations.

The report also has for its purpose the determination of future central station requirements of the district for a period of five to seven years, and recommendations are made for a unified connected system to supply the entire western Pennsylvania and eastern Ohio territory. The increase of power required from central systems will be made up of the increased power demands of present customers; of the power required to replace such portion of the power which at the present time is being generated inefficiently by separate isolated steam plants; and of the power requirements to meet the demands of new manufacturing industries; and also of possible needs of railroad electrification. The merits of and the advisability of the early electrification of railroads is not herein discussed as there is some doubt among the electrical engineers of the railroad companies as to the economic advantage of railroad electrification, except in specific instances. There are a few sections of the railroads leading into Pittsburgh that have heavy mountain grades where railroad electrification will not only effect an economy in railroad operation, but will also greatly increase the carrying capacity of these sections of the railroad which otherwise place a limit upon the long-haul capacity of the railroads. The item of this power requirement is given only to indicate the probable increased demands on central stations should electrification become an accomplished fact.

The report contains an outline of the construction program which the various public utilities have started upon in order to keep up with the growing power demands. The present tendency is to provide generating equipment in steam plants of large sizes, conveniently located to the coal mines and to an ample supply of condensing water. With these conditions satisfied, the plants are otherwise located as close to the points of power consumption as possible.

Although the future power requirements will be largely furnished from new steam-generating equipment, there are a number of favorable water-power resources within transmission-line distance of the

Pittsburgh district which should ultimately be constructed to conserve coal, reduce labor costs, and improve reliability of service. The development of these water powers, which are located on important tributaries of the Allegheny and Monongahela Rivers, will also assist in flood control in the improvement of navigation facilities and domestic water supply for the city of Pittsburgh.

SCOPE OF THE REPORT.

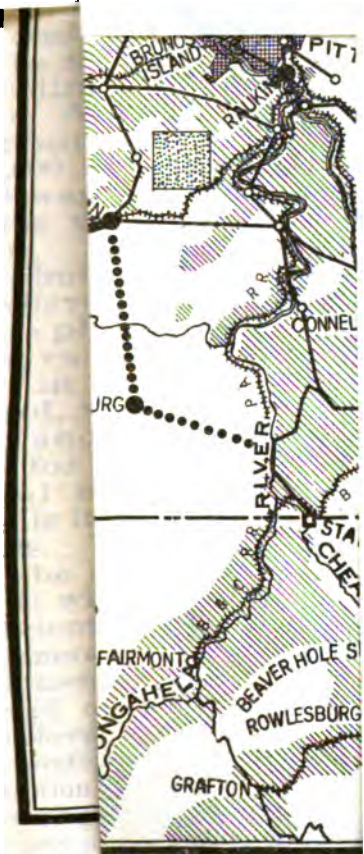
This report will be limited to the western part of Pennsylvania and the eastern part of Ohio. This area has been shown upon plate 1, upon which there is indicated the present high-voltage transmission lines used to distribute the power from the existing large steam power plants to the points of use. The district and transmission systems are divided into sections whose limits are more or less dictated by the sphere of operation of the public utilities operating therein.

The section served by the Duquesne Light Co. is the city of Pittsburgh proper, and extends outside of Pittsburgh and embraces practically all Beaver and Allegheny Counties. The West Penn Power Co. furnishes the power in the territory surrounding Pittsburgh and the Duquesne Light Co. district. It comprises the greater part of the southwestern corner of Pennsylvania. Some power is furnished in the Panhandle of the State of West Virginia. The Mahoning and Shenango Railway & Light Co. has generating stations at New Castle and Ellwood City, Pa., and Youngstown and Lowellville, Ohio. It supplies the power requirements in and near these cities. The American Gas & Electric Co. has generating stations and distributes power at Wheeling, W. Va., Steubenville, East Liverpool, Canton, Newark, and Fremont, Ohio. The Windsor power station near Wellsburg, W. Va., on the east bank of the Ohio River, furnishes a large amount of power to both the West Penn Power Co. and the American Gas & Electric Co., who are partners in ownership of this plant. The operating company of the Windsor plant is the "Beech Bottom Power Co." Henry L. Doherty & Co. own public utilities and plants at Warren, Alliance, Massillon, Mansfield, and Lorain, Ohio, serving these cities and some of the intervening territory. The Northern Ohio Traction & Light Co. has power plants near Akron, and serves the vicinities of Bedford, Kent, Akron, and Barberton. It supplies also a large amount of power for trolley service. In Cleveland, Ohio, there are the Cleveland Electric Illuminating Co. and the municipal plant of the city of Cleveland. The Ohio Service Co. has power plants at Coshocton and New Philadelphia, Ohio.

The power for trolley service is largely furnished by the North Ohio Traction & Light Co., with power plants near Akron, the Pittsburgh, Harmony, Butler, and New Castle Railway, with a plant at Harmony Junction, Pa., the Stark Electric Railroad Co., at Alliance, Ohio, the West Penn Power Co., and the Duquesne Light Co.

SOURCES OF INFORMATION.

Personal interviews were had with the operating management of each of the public utilities discussed herein. Plant operation and cost data were obtained from the companies. Information has also been



obtained from reports of Maj. C. F. Lacombe and John C. Damon, Engineers, U. S. Army, made to the War Industries Board and to the Chief of Engineers.

SUMMARY.

There was a shortage of power in the western Pennsylvania and eastern Ohio district during the war period of 1917 and 1918, and steps were initiated to remedy this condition, which resulted in a program for the addition of 300,000 kilowatts of new equipment to be placed in operation during 1919. With Government financial assistance, an installation of 40,000 kilowatts for the Springdale plant of the West Penn Power Co. and 8,000 kilowatts in the Lorain County Electric Co.'s plant at Lorain were contracted for. The power shortage was somewhat relieved by the cooperation between the various central station systems and by cooperation also with the customers. The occurrence of the influenza epidemic, which depleted the labor resources of the manufacturing companies, and the signing of the armistice in November prevented the accumulation of a power demand in December that might have been beyond the capacity of the central stations to furnish.

The total generating capacity in the power plants of the district, including the cities of Cleveland, Lorain, Akron, Warren, Youngstown, Alliance, Canton, Massillon, Mansfield, Newark, Coshocton, Pittsburgh, Connellsville, Wheeling, Windsor, and others amounts to 773,000 kilowatts. The total output of power from these stations in 1918 was approximately 2,440,000,000 kilowatt hours. The aggregate of the various power peak demands during 1918 was 568,000 kilowatts. Although these figures indicate reserve capacity, its actual distribution and the interconnection of the systems was not such as to relieve the 1918 shortage in the Pittsburgh district.

The plant cost of power, including only coal, labor, and plant repair costs, varied from something less than 5 mills per kilowatt hour to 25 mills in the inefficient central station plants. The cost of coal delivered, which in 1914 varied from \$1.06 to \$1.72 per ton, increased to \$2.79 and \$4.20 per ton in 1918. The present minimum value of coal used for power purposes is \$2 per ton.

Coal consumption per kilowatt hour generated varies from 1.8 pounds in the efficient plants to 9.2 pounds in the older and less efficient plants. There is such a wide variation in the rate of coal consumption and the cost of manufacturing power between the modern efficient plants with units of large capacity and those of the older plants with inefficient and small-sized units that a great economy can be procured by generating the power of the present inefficient plants with efficient equipment of large-sized units in the power plants which have been started or contemplated at Windsor, Cheswick, Springdale, and elsewhere. If the power now generated by the inefficient plants in the western Pennsylvania and eastern Ohio district with a coal consumption rate of over 2½ pounds per kilowatt hour and a power manufacturing cost of over 5 mills per kilowatt hour were generated in efficient plants at a coal consumption of 1.8 pounds, there is possible an annual saving of 796,000 tons of coal per year and of \$6,950,000 annually in plant operation cost.

Exclusive of isolated generating equipment in the larger steel companies, there exists in the district approximately 700,000 kilowatts of generating equipment installed in isolated power plants, of which, it is estimated, 460,000 may be economically replaced by central station service during the next five to seven years. This, with proper consideration to the diversified character of the isolated service, will increase the peak loads upon the central systems 205,000 kilowatts. The power which is now generated in these isolated plants is estimated at a coal consumption of 9 pounds per kilowatt hour. If the power were furnished from central station systems, there is possible a further conservation of coal in addition to that given above of 3,250,000 tons per annum and a probable saving in manufacturing cost of power of \$12,000,000 per year.

In addition, however, it is estimated that there is some 800,000 kilowatts of generating equipment—including electric, gas, and steam power—in the major iron and steel companies in this district. In view of the fact that steel companies have by-product fuel and waste heat, it is not probable that more than half of this will ever affect central station service. This would increase the peak demand by 180,000 kilowatts.

Central stations of this district serve an industrial manufacturing load. Of their total output, some 15 per cent is used for lighting, 65 per cent for power requirements, and 20 per cent for trolley service. Load factors on the various systems vary from 38 to 61 per cent, with a weighted average of 49.7 per cent for the district. The average diversity factor is about 45 per cent.

It is estimated that in order to meet the increased demands of present customers the requirements of isolated plants when supplied by central station service, and to meet the requirements of new industries, there will be additional central station power-generating equipment required adequate to furnish 2,200,000,000 kilowatt hours per year. This will require 530,000 kilowatts of new steam turbines and auxiliaries, which should be installed within the next five to seven years. In addition, 300,000 kilowatts of the present inefficient equipment in central stations should be bettered or replaced. It is estimated that within the same period the steel companies will require some 800,000,000 kilowatt hours of power per year from central stations, requiring an increase in capacity of 200,000 kilowatts. If all of the railroads in western Pennsylvania and eastern Ohio were electrified, their power requirements would be 2,400,000,000 kilowatt hours and would require an addition of 500,000 kilowatts in plant equipment.

In order to meet the power requirements for the next five to seven years it is recommended that the program which the central station systems have started upon be actively carried out and extended. In order to produce the cheapest power in this district it is necessary that power plants be located at points where abundance of coal supply is available and ample amount of condensing water is assured. Such locations necessarily fall along the Ohio River and the main tributaries thereof. The plants at Windsor and Springdale and the proposed plant at Cheswick meet with these conditions. They are on the Ohio and Allegheny Rivers and have, immediately adjacent to the plants, coal mines of ample capacity for some 25 years' dura-

tion at least. Next in importance for power-house locations there may be mentioned West Pittsburgh on the Beaver River, Warren on the Mahoning River, near Connellsville on the Youghiogheny River, and Bolivar on the Tuscarawas. The choice of the latter locations, though less favorable than the former, may be required because of the localized power demands.

Transmission-line systems of the major companies—that is, of the Duquesne Light Co., the West Penn Power Co., the Mahoning & Shenango Railway & Light Co., Northern Ohio Traction & Light Co., the Doherty interests, and the American Gas & Electric Co.—should be interconnected by transmission lines of ample capacity, and there should be a closer joint operation of the systems in order that the total required reserve capacity for the district may be reduced to a minimum, also in order that their reliability of service may be increased during emergency conditions, and, lastly, in order that only those plants economical in coal consumption and operation costs may be built.

POWER SUPPLY CONDITIONS DURING THE WORLD WAR.

There was a power shortage in western Pennsylvania and eastern Ohio district during the war period of 1917 and 1918. The district is one of the largest industrial manufacturing sections of the country, especially so in the manufacture of war material. Some 40 per cent of the total amount of steel required for munitions, steel ship construction, etc., was furnished from this district. Four-fifths of the country's blast furnaces are located here. In addition to the manufacturing interests, a large amount of bituminous coal is mined. Had an ample amount of power been available, the severity of the coal shortage during the war could have been partially relieved.

Early in the war, the urgent need of additional generating capacity was evident, but it was impossible for the central station companies to finance adequate extensions to their generating equipment. It was therefore necessary for the Government to lend the financial assistance that was finally given to the West Penn Power Co., the Lorain County Electric Co., and to the Duquesne Co. Arrangements were made with the first company to install 40,000 kilowatts of generating capacity at the new Springdale plant near Pittsburgh by the end of 1919 or the first part of 1920, and 8,000 kilowatts of capacity in the Lorain plant. The boiler capacity of Duquesne Co. was increased, which netted an increase of 15,000 kilowatts to the capacity of the plant.

Immediate remedy to the growing shortage was, however, necessary, and this was accomplished partially in three different ways. A better cooperation and interconnection of the transmission systems was established between some of the main central station companies. This permitted a freer exchange of power between the systems, and though it did not increase the amount of power materially, a greater reliability of power supply was obtained, in that reserve capacity in one system was called upon during the shortage on other systems. The cooperation of the power customers themselves was obtained, by which they were restrained as far as possible from calling for power during the maximum peak period and to take their supply during the off-peak periods of the day. The power requirements of the lesser or nonessential industries were curtailed to some extent.

During the middle of 1918 the largest generating unit in the district, a 40,000-kilowatt unit, was burned out. This accident called for immediate action. Some of the shortage was made up by curtailing the use of power in mercantile and office establishments during the peak period from 7.30 to 10 a. m. By this means a decrease of 4,500 to 5,000 kilowatts on the maximum peak was obtained. In addition, many contracts for new load were refused.

Under these circumstances a most serious shortage would have been reached at the end of 1918 had not the influenza epidemic occurred. There is normally an increase of some 20 per cent in maximum peak demand from September to December, due to the longer lighting hours and increase in power demands. The decrease in labor supply resulting from this epidemic curtailed very materially the amount of power required. Later, the cessation of war activities upon the signing of the armistice further curtailed the otherwise largely increased power requirements.

PART 2.

PRESENT GENERATING CAPACITY AND POWER PLANT OPERATION.

INSTALLED GENERATING CAPACITY.

The central station systems of western Pennsylvania and eastern Ohio district have at present the following installed generating capacity:

	Kilowatts.
Duquesne Light Co.....	157,450
West Penn Power Co.....	112,150
Mahoning & Shenango Railway & Light Co.....	58,000
American Gas & Electric Co.....	122,750
Henry L. Doherty & Co.....	75,450
Cleveland Electric Illuminating Co.....	148,900
City of Cleveland.....	18,000
Northern Ohio Traction & Light Co.....	69,175
Ohio Service Co.....	12,840
Stark Electric Co.....	2,300
	773,015

The Duquesne Light Co. have seven separate plants, with 75 per cent of the total capacity in one plant, that of Brunots Island. The West Penn Power Co. have 12 power plants, with 89 per cent of the capacity in two modern plants, Windsor and Connellsville. As will be discussed later, the other plants of this company are uneconomical in their operation and will sooner or later be shut down or held for emergency reserve service. They were, however, of valuable assistance in supplying power for war needs during the past two years. The generating capacity of the American Gas & Electric Co. is distributed among seven different plants. Forty-one per cent of this capacity is located at Windsor. Large capacities are also located at Canton, Newark, and Ballville. It is proposed at some time to extend the transmission lines of the Sunnyside division of this company from Barnesville to New Lexington, upon the completion of which all the generating plants of this company will be interconnected and will form one system.

The generating equipment of the Doherty properties is located in five different cities; 45 per cent of the total capacity is located at Warren, which promises to receive the greatest part of the industrial development.

Although it has been intended to include all of the electric power generating companies within the district, there are a few minor companies which it has been necessary to omit. They consist of the Youngstown & Ohio River Railroad Co. and the Salem Electric Co. They furnish power for trolley service. The West Virginia Traction & Electric Co. operates trolley systems in West Virginia, and has power plants at Elm Grove and Morgantown. Other compa-

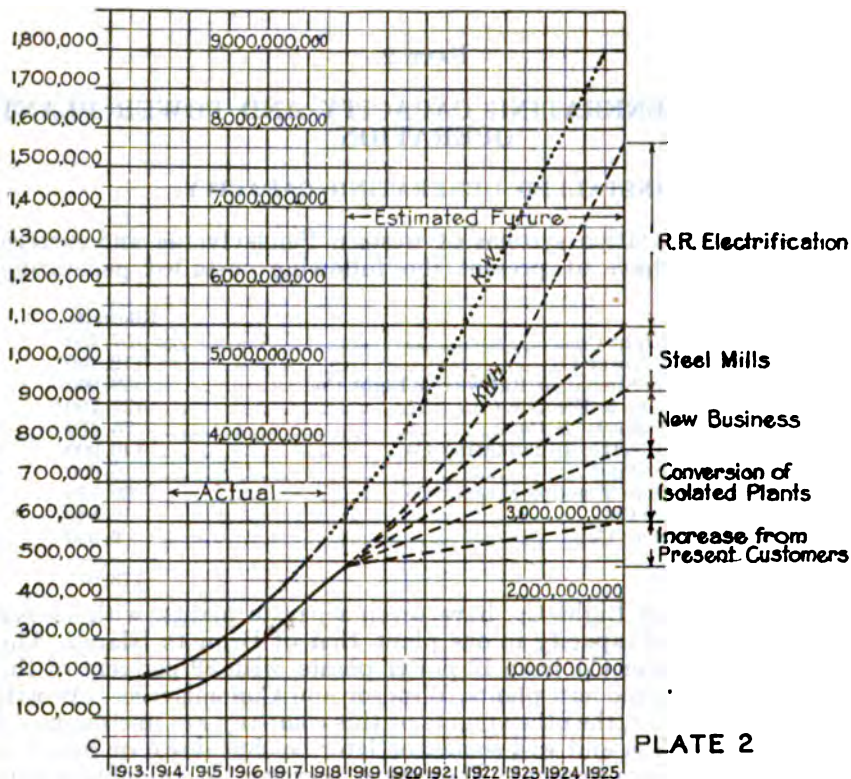
K.W. of Max-
imum Power
DemandK.W.H. Annual
Power Output
Required

PLATE 2

CURVES OF TOTAL ANNUAL POWER OUTPUT
AND MAXIMUM POWER DEMANDTo Accompany Report - T-20-19 by
Lyle A. Whitsett - Captain, Engineers.

BY DATE PARTS REVISED	POWER GENERATING CENTERS AND MAIN TRANSMISSION SYSTEM FOR PITTSBURGH, WESTERN PENN- SYLVANIA AND EASTERN OHIO DIST'S.		
	POWER CURVES		
	OFFICE OF THE CHIEF OF ENGINEERS, U. S. ARMY EQUIPMENT SECTION, TROOP DIVISION		
	DRAWN BY W. E. F.	TRACED BY W. E. F. 2005.	REVIEWED BY
	IN 2 SHEETS DRAWING LIST ON NONE		
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nies are the Monongahela Valley Traction Co., the Mercer County Light Co., and the Citizens Traction Co. at Oil City. The Lake Shore Electric Railway Co. operates a suburban railway near Sandusky, Ohio.

ANNUAL POWER OUTPUT OF CENTRAL STATION COMPANIES.

The annual kilowatt-hour output of the central station systems for the calendar year 1918 was as follows:

	Kilowatt hours.
Duquesne Light Co.....	641,900,000
West Penn Power Co.....	362,378,800
Mahoning & Shenango Railway & Light Co.....	188,572,000
American Gas & Electric Co.....	280,032,000
Henry L. Doherty & Co.....	144,332,800
Cleveland Electric Illuminating Co.....	543,663,000
City of Cleveland.....	67,482,000
Northern Ohio Traction & Light Co.....	181,662,300
The Ohio Service Co.....	25,505,400
Stark Electric Co.....	8,166,900

2,443,645,200

During the past six years there has been a decided and rapid growth in the output of the central stations of this district, as is indicated in Appendix 1 for the various systems and as shown graphically on plate 2. The maximum power demands which occurred in 1918 are itemized as follows:

	Kilowatts.
Duquesne Light Co.....	141,000
West Penn Power Co. (exclusive of purchased power).....	74,490
Mahoning & Shenango Railway & Light Co.....	35,000
American Gas & Electric Co. ¹	69,850
Henry L. Doherty & Co. ¹ (approximate).....	46,700
Cleveland Electric Illuminating Co.....	136,319
City of Cleveland.....	15,100
Northern Ohio Traction & Light Co.....	40,800
Ohio Service Co.....	5,900
Stark Electric Co.....	2,460

567,619

During February and March of 1919 there was some dropping off in power demands on the central station systems, due to the curtailment of manufacturing operations occasioned by war contracts. Since that time, however, there has been an increase, and the requirements on the central station systems have now reached a normal amount for this time of the year. In Appendix 3 is given the kilowatt-hour output for the first four or five months of 1919 (as indicated) for the central station systems.

The total amount of power generated by the Windsor plant for the year 1918 was 241,276,180 kilowatt hours, which was distributed to the systems of the West Penn Power Co. and the American Gas & Electric Co.

¹ Total of the maximum demands sustained on the individual plants.

PART 3.

COAL CONSUMPTION AND ECONOMY OF PLANT OPERATION.

PLANT COST OF POWER.

As used in this report, the cost of "manufacturing power" or "plant cost" is to include cost of coal, plant operation labor cost, and the cost of repairs. It does not include reserve funds set aside to cover depreciation, interest, or taxes.

PLANT ECONOMY.

There are three factors which enter into the economy of plant operation: First, there is that of accessibility of the plant to coal supply and condensing water. The proximity of a large coal supply eliminates the cost of freight in the production of power. An ample quantity of condensing water of low temperature makes it possible to obtain a high degree of vacuum and thereby greater efficiency in the prime mover. The benefits of accessibility may be offset by the remoteness of the power plant from the load center or from the point of the use of power. Freight on the transportation of coal, assuming that an ample supply of condensing water is available at either place, when balanced against the cost of transmission of power plus the value of the power lost in transmission determines the location of the power plant.

For the plants in this district which are favorably situated there should first be mentioned that of the Windsor plant, which is located on the Ohio River and obtains its coal supply from mines immediately adjacent to the plant. The Brunots Island plant at McKees Rocks and the Connellsville plant have ample condensing water, but minimum freight charges on the coal supply. The plants at Cleveland, Ohio, have the most favorable condensing-water conditions, but relatively high freight charges. During 1918 the Cleveland Electric Illuminating Co. made an economic study to determine whether future generating equipment should be built on the Ohio River adjacent to a bituminous-coal supply and the current delivered by high-voltage transmission lines to Cleveland, or whether their plant should be located on Lake Erie, at the load center, and with a more favorable supply of condensing water, but subject to a freight charge of \$1.10 to \$1.90 per ton on the coal supply. The present intention is to adhere to the Lake Erie location. Plants on the Mahoning River at Youngstown and at Warren have sufficient condensing water and average freight charges of \$1 per ton. The plants at Wheeling, W. Va., East Liverpool, and Steubenville are favorably situated for condensing water and coal supply, but are not efficient, mainly because of the age of the equipment and size of the units.

COAL ITEM IN POWER COSTS.

The second item entering into the economy of plant operation is the cost of coal. In addition to the Windsor plant the West Penn Power Co. is building a second plant on the Allegheny River at Springdale, with a low-price coal supply to be obtained from a mine immediately adjacent now being developed. The Duquesne Light Co. is contemplating a new plant at Cheswick, a short distance below Springdale on the Allegheny River. Conditions at these three sites make them favorable locations for the future addition of new equipment when compared to the other power plants in the district.

EFFICIENCY OF POWER PRODUCTION.

The third item entering into plant economy is the efficiency which is obtained in the prime mover and auxiliary plant equipment. High efficiency is obtained in the new modern design of steam turbines of large capacity, such as the 20,000 kilowatt and 30,000 kilowatt units now being installed at Springdale and at Windsor accompanied by modern type of boilers and motor-driven auxiliary equipment. Such plants permit the production of a kilowatt hour for the least amount of coal, a condition which can not be obtained in units of smaller size and equipment of older design. In addition to the less heat efficiency of the boiler and prime mover equipment of the older and smaller plants there is a greater labor cost because of the size and number of units and the lack of motor-driven equipment. Except for the efficient plants named above, the high plant cost of power in this district is largely due to old equipment, small sizes of units, and lack of efficient auxiliary equipment.

COST OF COAL.

Cost of coal is the main item entering into cost of power production. Freight on coal for the plants in this district varies from practically nothing at the plants located at the mines to \$1.90 per ton at the plants in northern Ohio. The No. 8, or Pittsburgh vein, and the Twin and Freeport veins in the Pittsburgh district are the source of coal supply for plants in the neighborhood of Pittsburgh and western Pennsylvania. Power plants in Ohio obtain their coal from different mines, such as local mines of Ohio; the Pittsburgh district Balkan, Ky.; Bellaire, Ohio; Cherry Valley, Pa.; Danville, Ohio; and Paint Creek, W. Va. For all plants the cost of coal in 1914 varied from \$1.06 to \$1.72 per ton delivered. In 1918 the corresponding cost varied from \$2.79 to \$4.20. Minimum present cost is in the neighborhood of \$2 per ton delivered. A greater use of electric power in the mining of coal will result favorably in the present and future cost of coal and power. A large part of the future prospects and growth of power demands on the system of the West Penn Power Co. is expected to come from the use of electric power from central stations for coal mining.

COAL CONSUMPTION.

Coal consumption per kilowatt hour for the central plants in this district in 1918 varied from less than 2 to 9.2 pounds of coal per kilowatt hour. Sixty-five per cent of the total kilowatt hours produced in 1918 were at a consumption rate of 2½ pounds per kilowatt

hour or less. Thirty-five per cent of the kilowatt hours was generated in 26 plants at a coal consumption of 2.5 to 9.2 pounds per kilowatt hour.

NOTE.—The poor economy in coal consumption during the year 1918 is due somewhat to a poor grade of coal which was obtainable during that year and to the inefficient labor, the trained forces of the boiler rooms having been depleted by army requirements.

UNIT COST OF POWER PRODUCTION.

The plant cost of power production, including only coal and labor costs and plant repair costs, varies from something less than 5 mills to 25 mills per kilowatt hour. Fifty per cent of the total power produced in 31 plants had a plant cost of 5 mills per kilowatt hour or less. The remaining power cost an average of 8.6 mills per kilowatt hour. One-half billion kilowatt hours had an average cost of 13.1 mills. If the 50 per cent of the power had been produced in a modern plant it would result in an annual saving of \$6,950,000. In addition to this, if the 905,000,000 kilowatt hours now produced annually inefficiently in isolated plants were generated in large central stations there would be an additional annual saving of at least \$12,000,000.

NOTE.—Data were not available indicating the plant operation cost for the Cleveland Electric Illuminating Co. The equipment of the company is efficient and it comes within the first class of power produced, that is, at less than 5 mills per kilowatt hour.

FUTURE ECONOMY OF POWER PRODUCTION.

The production of cheap power for the future requires that new generating equipment shall consist of units of large capacity such as are used at Windsor, and contemplated at Springdale and Cheswick by the West Penn Power Co., and the Duquesne Light Co. The development of water power should be given greater consideration. The increase in new generating equipment must be such as not only to meet the growing demand for power but also to permit shutting down the present central station plants which are inefficient and which are being operated at a high plant cost. A better interconnection of the central station systems is desirable for economy of power production as it will cut down the total amount of reserve generating equipment required for the district. A closer interoperation of the systems will secure greater reliability of power supply, and will also permit the better location of new generating equipment to meet economic requirements. It will produce a lower diversity factor, that is, a kilowatt of installed capacity will serve a greater number of customers.

COAL CONSERVATION.

Coal consumption in the best plants is considerably under 2 pounds per kilowatt hour. The plants, such as contemplated at Springdale and Cheswick, should have an economy equal to the best plants. As pointed out elsewhere, these plants will be used not only to supply new load demands, but to shut down and replace the load upon

the less efficient plants. However, it is not probable that within the next five years plants of a consumption of $2\frac{1}{2}$ pounds per kilowatt hour and with normal operating costs will be shut down or put into the discard class. Therefore, for the period under consideration, it is hardly proper to count on any economy except that possible in the balance of the power output, that is, that requiring at present a consumption of greater than $2\frac{1}{2}$ pounds per kilowatt hour. On the basis of 1918 there were 760,000,000 kilowatt hours of power generated in the less efficient central station plants of western Pennsylvania and eastern Ohio by the use of 2,963,000,000 pounds of coal, having a total cost of \$4,814,179. This amount of power produced in modern plants at a consumption rate of 1.8 pounds per kilowatt hour and at plants located adjacent to coal mines would effect a saving of 796,000 tons of coal per year. In addition to this, if the 905,000,000 kilowatt hours now produced in isolated steam plants with assumed consumption of 9 pounds per kilowatt hour were produced by efficient steam plants there would be a further conservation of 3,250,000 tons of coal.

NOTE.—Wherever possible, the inefficient plants are now shut down during the night, Saturday afternoon, and Sunday periods, and are placed upon the line only when the efficient equipment is not sufficient to carry the total load. For example, the Canton plant was placed in operation only during the day and was shut down during the night and all day Sunday. With the addition of increased capacity to the systems these plants will be shut down practically all the time and will be used for reserve purposes.

PART 4.

CHARACTER OF POWER AND ITS USE.

DISTRIBUTION OF POWER.

The use of electric power now generated in the western Pennsylvania and eastern Ohio district is confined mostly to lighting, power, and railway purposes. By railways is meant city and suburban trolley systems. The power use includes that for all motor-driven manufacturing purposes, electric furnaces, and electrical heating. The total central station output is used for the different purposes in the following proportions:

	Per cent
Lighting.....	15
Power.....	65
Railways.....	20
	<hr/> 100

PEAK LOAD.

The peak loads sustained by the various systems during 1918 have been given above.

LOAD FACTORS.

The annual load factors vary for the different systems from 38 to 61.5 per cent. The weighted average annual load factor for the entire district for the year 1918 is 49.7 per cent.

CONNECTED LOAD.

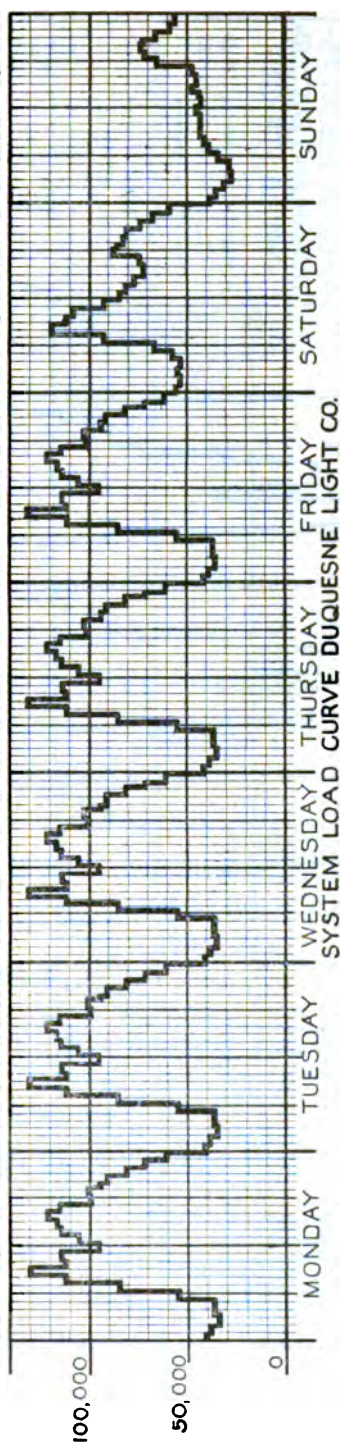
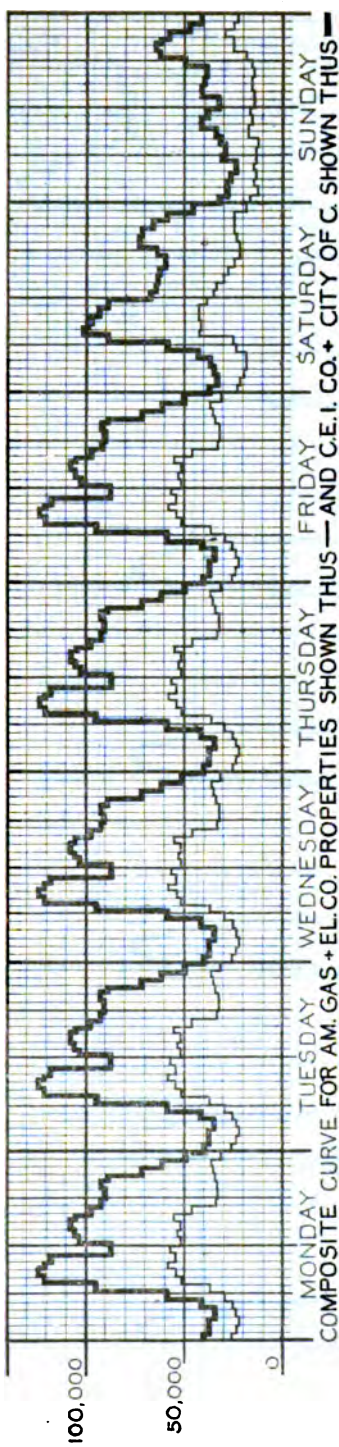
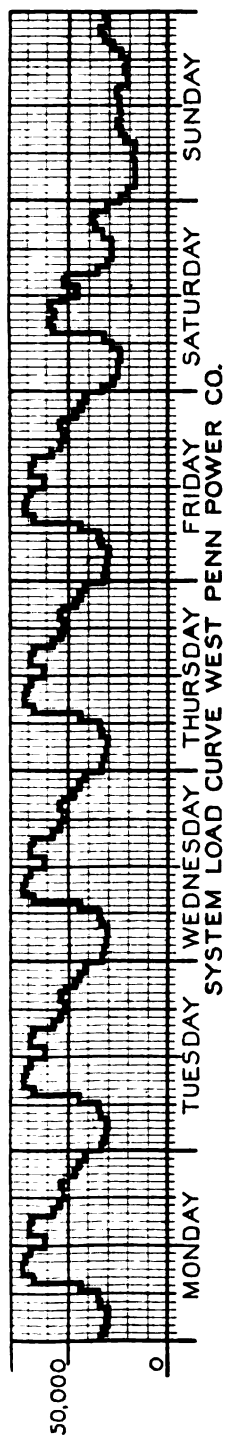
The connected load of the Duquesne Light Co., consisting only of its light and power load, amounts to 286,100 kilowatts; that for the West Penn Power Co. is 188,500 kilowatts including railways; the Mahoning & Shenango Railway has a connected load of 93,000 kilowatts. The corresponding diversity factors are 33 per cent, 43 per cent, and 39 per cent.

FREQUENCY—CYCLES.

In general, the current produced by central stations for power and lighting purposes is 60-cycle current and for some trolley systems 25-cycle current. The current produced by the larger steel companies is mostly 25-cycle current.

LOAD CURVES.

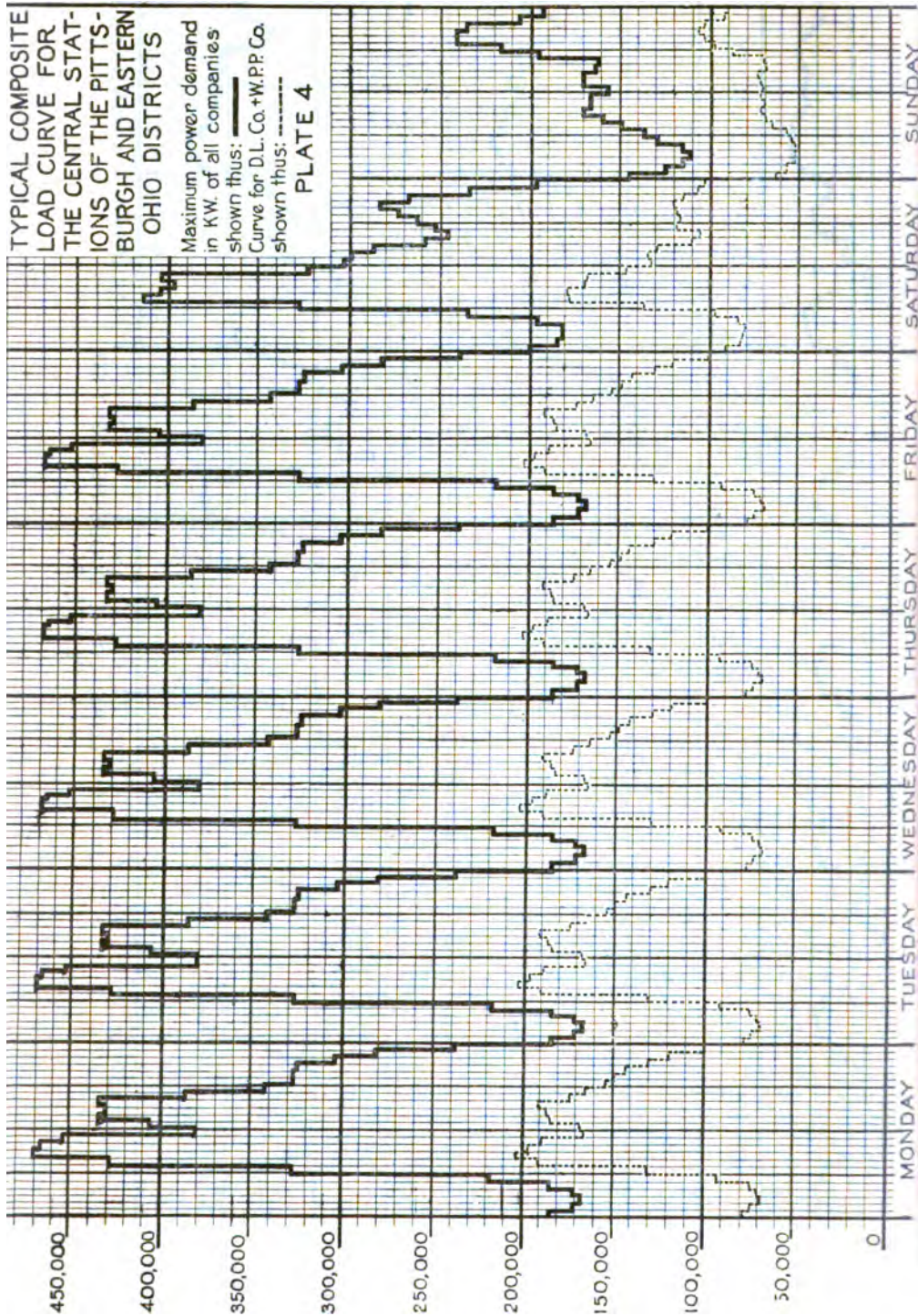
Typical week day, Saturday, and Sunday load curves for some of the larger systems are shown upon plates 3 and 4, upon the latter of which is superimposed also a composite load curve for the entire



TYPICAL COMPOSITE
LOAD CURVE FOR
THE CENTRAL STAT-
IONS OF THE PITTS-
BURGH AND EASTERN
OHIO DISTRICTS

Maximum power demand
in K.W. of all companies
shown thus: ———
Curve for D.L. Co. + W.P.P. Co.
shown thus: - - - - -

PLATE 4



district. This curve is presented to show the characteristics of the variation of load during the day and during the week. It has a weekly load factor of 63 per cent. It is to be referred to again under the caption of "Water-power developments."

There is at present a difference of time of one hour between the Pittsburgh section of western Pennsylvania and the Ohio districts. This, if it were maintained, would make possible a diversity in the peaks of the two localities. However, upon the repeal of the daylight-saving law, and assuming that the present railroad time will be used, which changes at a point west of the Ohio district and not within the limits of the territory here considered, the schedule for the two localities will be the same and the peaks will be more or less coincident.

PART 5.

POWER REQUIREMENTS FOR THE FUTURE FIVE TO SEVEN YEARS.

ADDITIONAL REQUIREMENTS OF PRESENT CENTRAL STATION CUSTOMERS.

For lighting.—In general, the increase in power requirements for lighting may be taken at 10 per cent compounded annually, which includes the increased demands of present customers and new light business. For a five-year period, there would be an increase of 60 per cent of the present lighting loads. In arriving at the future requirements, this percentage of increase in the present lighting load has been used for five to seven years.

For power.—The power load of the various systems increases at an average rate of 13 to 15 per cent compounded annually. This for a period of five years would result in an increase of 100 per cent to the present power load. However, such an estimate includes, in addition to the increased demands of present customers, the power required for new industries and conversion of isolated power plants. In this report, the items for the last two requirements are estimated separately, and, it is believed, more accurately than would be the case in an assumed, fixed, and uniform, percentage. Therefore, in order to cover the amount of additional power required for present central station customers, 2 per cent compounded annually, or 13 per cent of the present power demands, will be added for a five to seven year period.

Railway load.—It is estimated the increased power supply required for the next five to seven years for trolley operation will be from 15 to 25 per cent of the present requirements and 20 per cent is used for the purpose of figuring.

TABLE 1.—*The estimated amount of power required to meet increased demands of the present customers of central stations.*

Territory served by—	Estimated increase in the demands of present customers.		
	Lighting.	Railway.	Power.
	<i>Kilowatt hours.</i>	<i>Kilowatt hours.</i>	<i>Kilowatt hours.</i>
Duquesne Light Co.....	51,000,000	35,000,000	45,000,000
West Penn Power Co.....	22,000,000	10,000,000	25,000,000
Mahoning & Shenango Ry. & Light Co.....	35,000,000	5,000,000	15,000,000
American Gas & Electric Co.....	25,000,000	5,000,000	27,000,000
Henry L. Doherty & Co.....	25,000,000	5,000,000	20,000,000
Cleveland ¹	65,000,000	30,000,000	50,000,000
Stark Electric Co.....	90,000	2,000,000	100,000
Northern Ohio Traction & Light Co.....	10,000,000	10,000,000	15,000,000
Ohio Service Co.....	3,000,000	500,000	2,000,000
Total.....	236,090,000	102,500,000	209,100,000
Grand total.....			547,690,000

¹ Including territories of the Cleveland Electric Illuminating Co. and the city's plant.

Isolated steam and gas plants.—For the items of isolated plants and new business, valuable information was obtained from the cen-

tral station companies, which was the result of intensive surveys which they had made in their individual districts and which indicate a large number of isolated steam plants generating a large amount of power that can be more economically furnished from central stations. See Appendix No. 4.

The power which could thus be supplied from central station service more economically as to cost of power and as to conservation of coal and labor is estimated as follows. It is the power that would be required of central systems, and has been arrived at after making proper deductions for availability.

TABLE 2.—*Power requirements of central systems to replace that now generated in isolated plants.*

Territory served by—	Kilowatt hour.
Duquesne Light Co.....	180,000,000
West Penn Power Co.....	370,000,000
Mahoning & Shenango Ry. & Light Co.:	
In Pennsylvania.....	32,000,000
In Ohio.....	38,000,000
American Gas & Electric Co.....	25,000,000
Henry L. Doherty & Co.....	40,000,000
Cleveland ¹	160,000,000
Stark Electric Co.....	
Northern Ohio Traction & Light Co.....	50,000,000
Ohio Service Co.....	10,000,000
Total.....	905,000,000
Power generated in steel manufacturing plants.....	720,000,000

¹ Exclusive of any of the large steel manufacturing plants.

² Including territories of the Cleveland Electric Illuminating Co. and the city's plant.

Isolated steam plants are not as a rule connected to the central station systems, and in nearly all cases they are of small size. Accordingly, the consumption of coal per kilowatt hour of the power which they generate and the unit cost of power are in excess of that of the power produced by central stations.

One exception should be mentioned to this statement, and that is the case of isolated plants belonging to the steel companies. Here, much of the fuel supply is obtained from waste heat and gas from blast furnace operation, which is used for the production of steam and indirectly for the production of power. Such a fuel supply, being a by-product, is figured as adding nothing to the cost of power production. This may not always remain true, however, for when a more valuable use for the gas is obtained, it may result that power can be produced cheaper from coal. Even at the present time, approximately half the power used by the steel companies is produced directly from coal burned under the steam boilers. It is not proper to assume that all the isolated plants in steel companies are future prospects for central station systems. In several instances, as in the case of the Carnegie Steel Co., the requirements for power are large, and a number of its steel plants are located in one district. It is possible for such a steel company to construct and operate a central system of its own, using efficient units of large size and the transmission of power at relatively high voltage. In addition to this, steel companies own mines of their own and obtain coal at a low cost for manufacturing purposes and incidentally for power production. It is therefore possible for them to locate their generating plants near such mines. For the purpose of this report, it will

be assumed that only half of the isolated power plants belonging to steel companies in the district are to be classed with other isolated plants as future prospects for the central station systems. This item for steel companies will be added as a separate item distinct from the compilation of other isolated plants.

In regard to isolated plants other than those in steel mills, there are some in which exhaust steam is used for heating. Others are of small capacity and not within economic transmission distance of central stations. It is not proper therefore to assume that all of them are available as future prospects or will be connected with the central station systems within the next five years. An arbitrary portion, generally 60 per cent of such isolated equipment, is estimated as available for central station systems within the next five to seven years. The price of central station power and the reliability which is required by the consumer and which can be furnished by the central stations affect this percentage. The ratio between this aggregate of the individual loads or isolated plants are the maximum central-station load required to supplant the isolated plants is further reduced by the diversity factor. For estimating purposes the diversity has been figured on the same percentage factor as prevails on the existing systems in those sections.

The isolated plant equipment in the district of West Penn Power Co. consists mainly of that owned and operated by coal mining companies, and glass and other manufacturers. That in the Duquesne Light Co. district consists of equipment used in the manufacturing of iron, steel, steel furnaces, railway shop operation, etc. That in the Mahoning & Shenango Railway & Light district is located in steel plants, railroad shops, or is used in the manufacturing of stoves, paper, rubber, cement, glass products, engine equipment, etc., and in the district of the Doherty properties it is used in the manufacturing of steel and railroad equipment and for the operation of dock loading and unloading equipment, etc., and in Cleveland consists in equipment used in textile, iron, and steel industries, dock machinery, building elevators, miscellaneous manufacturing, and the production of chemicals, rubber, and in furnaces.

Power requirements for new business.—The estimated requirements of central station systems necessary to supply the electrical power that will be required for new industrial business, including requirements of power for electrical heating and electrolytic purposes, are as follows:

TABLE 3.—*Power requirements of central station systems to supply new business.*

Territory served by—	Kilowatt hours.
Duquesne Light Co.	100,000,000
West Penn Power Co.	125,000,000
Mahoning & Shenango Railway & Light Co.	40,000,000
American Gas & Electric Co.	95,000,000
Henry L. Doherty & Co.	230,000,000
Cleveland Electric Illuminating Co. and the City of Cleveland	120,000,000
Northern Ohio Traction & Light Co.	30,000,000
Ohio Service Co.	27,500,000
Total	745,500,000
Steel companies	80,000,000
Grand total	825,500,000

Central stations power required for the conversion of isolated power in steel manufacturing plants.—From a survey of the power-generating equipment in the steel mills, consisting of those of the United States Steel Corporation, Jones & Laughlin, Crucible Steel, and the large independent companies of western Pennsylvania and eastern Ohio, it was found that there is approximately 380,000 kilowatts in electrical generating equipment, and, in addition, there is approximately 630,000 horsepower of steam engines, gas engines, and other power used for power purposes other than the generation of electric power. Half the power is produced from waste heat and gas by-product fuel. The remaining half of the power is produced from coal in the usual manner. It is believed that steel companies will find a more valuable use for some of the gas now used in power production, so it is estimated that half of their power requirements should and will be furnished from central-station service. The estimated aggregate central-station demand for this work has been further reduced by an assumed percentage of availability and diversity of loads. Future power requirements to meet this demand for the next five to seven years will be approximately 720,000,000 kilowatt hours per year, or an increase of 180,000 kilowatts upon the central-station power peaks.

NOTE.—The waste heat and gas by-product fuel used by steel companies for power generation does not include what is commonly known as "by-product gas"; that is, the gas resulting from the production of coke from coal. It is too valuable for this use. Benzol, toluol, and other by-products are recovered from the gas, and the heat value resulting from the balance is used for other purposes than steam production.

NOTE.—It has been the experience of the large steel companies that though the gas by-product fuel which they obtain in their manufacturing operations would give a total heat efficiency of 20 per cent if used in gas engines, yet actually cheaper power is produced when the same gas is used under boilers to produce steam for steam turbines with only an over-all heat efficiency of 10 to 15 per cent. There is one case of a plant in which six 500-ton blast furnaces produce sufficient by-product fuel to generate 15,000 kilowatts of electric current.

Power required for railroad electrification.—It is to be expected that the railroad lines passing through Pittsburgh and this district will at some future time be electrified. There is a heavy suburban traffic on the Pennsylvania lines from the suburbs into the city of Pittsburgh, and the main lines are more or less congested at the present time from the through passenger and freight traffic.

The railroads leading into Pittsburgh have heavy grades for a portion of the divisions out of this city, which make electrification favorable for such portions of the line, if not for the entire division. Railroad electrification of all of the lines would hardly be expected within the period covered by this report, but it will probably be undertaken on some of the more favorable sections. During 1918 the Pennsylvania Railroad gave serious consideration to electrification of that portion of the Pittsburgh division from Altoona to Johnstown, which, under the conditions that existed at that time, was the most economical way of overcoming a serious congestion of traffic. The merits of electrification and operation versus continua-

tion of steam-locomotive operation are not discussed in this report further than to set out the amount of power that will be required for the electrification of the railroads in the vicinity of Pittsburgh should such electrification be made. It may be said, however, that in addition to increasing the capacity of congested portions by 100 per cent the cost of railroad operation would be greatly decreased.

It is more than likely that power supply for electrification will come largely from central station systems, in that central-station companies have now established large transmission-line systems and large extensions of their power-generating equipment, which will guarantee a source of power in the large blocks that is required for electrification, and also absolute reliability, which is the most essential feature in railroad operation, and, further, the central-power systems will become stronger and more reliable as their equipment is increased.

The availability of central-station power will relieve the railroads of this part of their problem—that is, the problem of financing that part of the investment for generating equipment, which is a large item. It also diminishes the amount of investment required for reserve generating capacity in that the reserve capacity existing in the central-station systems will be ample, and it will only be necessary for the central-station systems to provide additions to their generating equipment amounting to the usable quantity needed by the railroads. The earning capacity of the central-station companies should provide ample credit for financing power-plant additions required for railroad electrification.

Power requirements for the electrification of the main railroads into and out of Pittsburgh have been considered and, in general, for a distance equal to a present operating division from Pittsburgh. On the Pennsylvania Railroad, the section from Altoona to Johnstown is the most favorable for electrification. It consists of 12 miles of 2 per cent average grade and 24 miles of 1 per cent average grade. Operation of this section would require a peak power demand of at least 33,000 kilowatts. The railroad company has gone so far as to build an experimental locomotive for this division. On the Baltimore & Ohio Railroad the most favorable section for electrification is that of the mountain grade in West Virginia from Grafton to Keyser, a distance of 78 miles and a maximum grade of 2.4 per cent. It is to be noted that this section passes near the Cheat River water-power development, which, if developed, would furnish power for this purpose. The Connellsville division of the Baltimore & Ohio favorable for electrification has 101 miles of 2.2 per cent ruling grade. The Bessemer & Lake Erie Railroad is 145 miles long from North Bessemer to Conneaut. Its freight consists mainly of ore and coal traffic. The Pittsburgh & Lake Erie Railroad is also considered, and also the Baltimore, Rochester & Pittsburgh Railroad.

In Appendix No. 5 is given the estimated kilowatt-hour requirements of power for electrification of the above-named railroads, together with the maximum peak on the basis of varying load factors, which depend upon the character and amount of traffic handled in each case. It is estimated that a total of 2,400,000,000 kilowatts and a combined peak demand of 500,000 kilowatts would be required for the electrification of all of these railroads.

TOTAL FUTURE POWER REQUIREMENTS.

The total estimated future power requirements include power necessary: (a) To meet the growing demands of the present consumers, (b) for the conversion of those isolated plants which should be changed to central-station service, (c) for new business requirements, and (d) for railroad electrification. The total estimated increase of central-station power needed by 1925 or 1926 is given as follows. This is a summation of the figures of Tables 1, 2, and 3.

TABLE 4.

Territory or district served by—	Estimated total needed increase in central station supply.	
	Kilowatt hour.	Peak increase, kilowatts.
Duquesne Light Co.....	411,000,000	90,000
West Penn Power Co.....	540,000,000	117,000
Mahoning & Shenango Ry. & Light Co.....	165,000,000	30,000
American Gas & Electric Co.....	177,000,000	45,000
Henry L. Doherty & Co.....	310,000,000	100,000
Cleveland ¹	425,000,000	106,000
Stark Electric Co.....	2,190,000	600
Northern Ohio Traction & Light Co.....	105,000,000	25,000
Ohio Service Co.....	43,000,000	15,000
Total.....	2,198,190,000	527,600
Steel companies.....	800,000,000	200,000
Railroad electrification.....	2,400,000,000	500,000
Grand total.....	5,398,190,000	1,227,600

¹ Including territories of the Cleveland Electric Illuminating Co. and the city's plant.

TABLE 5.—Estimated installed generating capacity needed by 1926 in the territory of western Pennsylvania and eastern Ohio.

Territory served by—	Present maximum central station peak load.	Peak increase in 5 to 7 years.	Estimated peak in 1927.	Estimated installed efficient capacity required by 1926.
	<i>Kilowatts.</i>	<i>Kilowatts.</i>	<i>Kilowatts.</i>	<i>Kilowatts.</i>
Duquesne Light Co.....	140,000	90,000	230,000	270,000
West Penn Power Co.....	80,000	110,000	197,000	230,000
Mahoning & Shenango Ry. & Light Co.....	35,000	30,000	65,000	90,000
American Gas & Electric Co.....	70,000	45,000	115,000	150,000
Henry L. Doherty & Co.....	46,000	100,000	146,000	175,000
Cleveland.....	150,000	105,000	255,000	300,000
Stark Electric Co.....	2,500	3,100	5,600	5,000
Northern Ohio Traction & Light Co.....	40,000	25,000	65,000	90,000
Ohio Service Co.....	8,900	15,000	20,900	25,000
Total.....	569,400	527,600	1,097,000	1,335,000
Reserve capacity.....			238,000	
Steel companies.....		200,000	200,000	225,000
Railroad electrification.....		500,000	500,000	500,000
Reserve capacity.....			1,797,000	2,060,000
			263,000	

PART 6.

RECOMMENDATIONS AND LOCATIONS FOR NEW GENERATING EQUIPMENT.

PROGRAM CONTEMPLATED PREVIOUS TO WAR.

Prior to the war some of the major power companies in western Pennsylvania and eastern Ohio designed plants and ordered machinery for large additions to their generating systems aggregating for the Duquesne Light Co., the West Penn Power Co., Mahoning & Shenango Railway & Light Co., the American Gas & Electric Co., the Doherty properties in eastern Ohio, and others, 300,000 kilowatts installed capacity to be placed in plants designed for an ultimate capacity of more than double this amount.

After the signing of the armistice and during the early part of this year, it was expected that the above construction program would be curtailed considerably. There was a falling off of maximum kilowatt demand and a greater falling off in kilowatt hour requirements. At the present time, however, the load is back to the normal conditions of 1918, and it is expected that the usual increase in demand will be present at the end of the year. Generally, the midsummer load is 15 per cent less than the January peak, whereas the December increase amounts to 20 per cent in excess of the previous January load.

RECOMMENDATIONS FOR NEW POWER GENERATING EQUIPMENT.

In order to meet the normal increase of power demand from the present customers, and provide for the conversion of isolated steam and gas plants, and for new applications of electric power, it is strongly recommended that an active construction program be carried on to increase the present central station equipment of western Pennsylvania and eastern Ohio district by 550,000 kilowatts to a total of, including present equipment, 1,335,000 kilowatts. In addition 300,000 kilowatts of present inefficient equipment in central stations should be bettered or replaced by modern equipment.

With the proper rearrangement of the existing transmission lines of the West Penn Power Co. and with the addition of new transmission lines to their system, the Springdale plant on the Allegheny River will take the power load to the north, northeast, and east of Pittsburgh. The present Connellsville plant will be connected with the Springdale plant by transmission lines of ample capacity for interchange of power. The Springdale plant will relieve the steam plants at Butler, Ligonier, and Creighton, which have a high coal rate, and the gas-engine plant at Kittanning. The Springdale plant will also be connected by ample capacity to the so-called "Pittsburgh ring," the transmission system of the Duquesne Light Co. surrounding the city of Pittsburgh, and a connection will be made to the pro-

posed Cheswick plant of the Duquesne company in order that there may be an exchange of power between the two companies during emergency conditions.

The Windsor plant, operated by the Beech Bottom Power Co., now installed for 90,000 kilowatts and soon to be increased to 120,000 kilowatts, will have a reliable capacity of 90,000 kilowatts, allowing one unit for spare requirements. Of the 90,000 kilowatts, 40,000 are contracted for the service of the West Penn Power Co. This capacity will be used to supply power to the south and west of Pittsburgh, and will permit shutting down the existing inefficient steam plants at Washington and the gas plant at Waynesburg as soon as the transmission line connection is made to the latter plant. The plant will be required to supply the growing requirements of mining operations.

Fifty thousand kilowatts of active capacity at Windsor, to serve the American Gas & Electric Co., should be used to relieve the plants at Steubenville and East Liverpool, which are the most inefficient plants on this company's system. Ultimately the Windsor capacity will be used to shut down the Wheeling and Canton plants of the same company, and will be used to meet the new business demands near Wheeling, and in southeastern Ohio. At Canton and at Akron, which is connected by a 132,000-volt line to Canton, there is a rapidly increasing market in rubber and other miscellaneous manufacturing.

The Lowellville plant of the Mahoning & Shenango Railway & Light Co. is relatively an efficient plant. The plants at North Avenue, Youngstown, and at Ellwood City, Pa., are inefficient plants and should be supplied by power from a new modern plant. A site has been selected by the Mahoning & Shenango Railway & Light Co. for a new steam plant on the Beaver River at West Pittsburgh, designed for a capacity of 60,000 kilowatts. The transmission lines of the Mahoning & Shenango Railway & Light Co. should be connected by ample capacity with the systems of the West Penn Power Co. and the Duquesne Light Co.

As part of the war program, the Henry L. Doherty & Co. contemplated the construction of a 25,000-kilowatt plant at Bolivar. There is a need of an efficient plant to shut down the inefficient plants at Alliance and Massillon. The Bolivar site is said to be suitable for developing 60,000 kilowatts, but as there is such a probability of greater increase in power demands upon this company's system at these and the plants at Lorain and Mansfield, a more comprehensive study and program of construction seems desirable, and may result in a choice of another location instead of the Bolivar site. Should the Bolivar location be chosen, or any other location in this part of Ohio, it should be interconnected by a transmission line of ample capacity to the Windsor plant, through the existing transmission line which extends from Windsor to Akron.

RELATIVE LOCATION OF COAL RESOURCES AND POWER PLANTS.

On Plate No. 1 there are shown some of the natural coal resources as they have been made evident by existing commercial coal mines. The map also shows by the principal rivers drawn thereon the more important sources of condensing water. Some of the rivers are, however, limited by low summer flow accompanied by high-water tem-

perature. The Ohio River and the main tributaries thereof are the most important sources for condensing water. This fact and the abundance of coal supply indicate that the best locations for steam plants are along these waterways. These conditions indicate that the locations at Windsor, Springdale, and Cheswick, West Pittsburgh, and Connellsville are favorable.

WATER-POWER RESOURCES.

Clarion River development.—The most important water-power sites are those on the Clarion and Cheat Rivers. The Clarion River is the second tributary in importance of the Allegheny River. It drains 1,250 square miles, of which some 63 per cent of the area still remains timbered. It has an average flow of 2,200 second-feet of water. There are two sites, one at the mouth of the river near Foxburg and the other at or near Clarion, Pa. At both sites, dams of approximately 250 feet in height may be constructed. Extensive surveys have been made of physical characteristics determining the water-power resources of this river. The two dams above mentioned will provide a total usable storage capacity of 40 billion cubic feet, which is sufficient to completely regulate the river to a continuous uniform flow in a year of average stream flow. This storage will make available some 650,000,000 kilowatt hours of prime power in an average year and 420,000,000 kilowatt hours in a year of extreme low-water flow. The sites are some 40 miles in transmission-line distance from the "Pittsburgh ring" of the Duquesne Light Co. and 25 miles to a connection with the system of the West Penn Power Co. This fact, together with the existence of a large central system load in western Pennsylvania, makes it favorable to install a large generating capacity at each of the two sites, which should be used to carry the peak load of the major power systems of western Pennsylvania during week days. That is, this water power would possess its greatest value when used to take the peak load of the western Pennsylvania district, assuming that the present steam plants and new steam plants that will be installed will carry the base portion of the load for six days of the week and all of the load on Sunday. It is estimated that, as above recommended, the two sites should be installed for an aggregate total of 300,000 kilowatts at an approximate cost of some \$28,000,000. This estimate is based upon prewar costs plus 40 per cent, and includes purchase of lands and franchises, necessary highway and railroad changes, concrete structures, turbine and electrical equipment, transmission system between the two sites, and a 40-mile transmission line with step-up and step-down transformers of ample capacity and proper reserve to supply 300,000 kilowatts of power to the Pittsburgh district.

There would be improvement to navigation facilities resulting from the increase in the low-water flow of the Allegheny River that would be obtained by the regulation of the natural stream flow of the Clarion for power purposes by the above storage capacity. The low-water flow of the Allegheny in September, 1908, was 990 second-feet of water at Pittsburgh. The storage capacity on the Clarion River is capable of being used for the improvement of flood con-

ditions also. Its water being clearer than that of the Allegheny River, and the presence of large settling reservoirs, would make this river a favorable source of domestic water supply for the city of Pittsburgh.

Cheat River development.—The Cheat River is a tributary of the Monongahela River and drains 1,415 square miles above a point where the river crosses the West Virginia-Pennsylvania State line. The drainage area is mostly within the State of West Virginia. This river has a mean annual flow of 3,130 second-feet of water from a drainage area of 1,380 square miles. The average run-off is 2.37 second-feet per square mile. The lowest annual flow of which there is any record occurred during 1904. It amounted to a mean flow of 2,060 second-feet for the period September 1, 1903, to August 31, 1904, or an average flow of 1.49 second-feet per square mile.

Among the possible water-power sites on the Cheat River and its tributaries, at least six are worthy of consideration and will conserve nearly all the power resources of this river. Of these, the first is the State line development, which consists of a dam and power house near the State line. Part of the dam, including foundations for four turbine installations, was finished July, 1913, since which time no additional construction has been done. When completed, this development will have an average effective head of 81½ feet and will be installed for 36,000 kilowatts. Its storage capacity is small and will be used only for daily regulation.

The second development is known as the Beaver Hole development. It will be made possible by a dam across the Cheat River just above the backwater from the State line development. The construction of a 250-foot dam is possible. Some storage capacity will be created by this dam. It has not, however, been taken advantage of in the determination of the power, as its main purpose is the creation of a pressure head. Large storage capacities are included in the other developments.

The third development is one proposed on the Big Sandy, a tributary of the Cheat River. It is a development made possible by the construction of a dam on the Big Sandy above Rockville. A 216-foot dam will produce a storage capacity of 225,000 acre-feet.

The fourth development will be made possible by a dam on the Cheat River 1½ miles, approximately, below the confluence of Muddy Creek, where the construction of a 250-foot dam is possible. Some storage capacity will be available at this site, though the main purpose of the dam is to create a pressure head.

The fifth development made possible by the construction of a dam across the Cheat River above Rowlesburg is chiefly a reservoir development. A rough estimate from the United States Geological Survey maps indicates that, at a maximum reservoir elevation of 1,625 feet, this site will have a usable storage capacity of 600,000 acre-feet. A power house, turbine, and electrical generating equipment should be provided at or near the dam.

The sixth development is known as the Blackwater development. It consists of a proposed dam for a storage reservoir on Blackwater River above the town of Davis, W. Va., and will have a capacity of 125,000 acre-feet. A net average head of 1,250 feet is available from this development by the diversion of water at a point below the town

of Davis and conducting it by flume to a proposed power-house location on Dry Fork above the town of Hendricks.

The completion of the State line and the construction of the Blackwater development are definitely recommended as the first step in the development of the Cheat River water powers. It is estimated that the completion of the State line development, including the installation of 36,000 kilowatts of generating equipment and transmission lines sufficient for transmitting the power of this development to Pittsburgh, will cost \$2,500,000 on the basis of prewar cost plus 40 per cent. The Blackwater development is estimated to cost \$4,500,000 for lands, structures, and installation of 33,000 kilowatts of generating equipment and sufficient transmission capacity for delivering the power at or near Pittsburgh. A combination of these two developments and the utilization of the storage from the Blackwater reservoir will generate 290,000,000 kilowatt hours of primary electrical power at the switchboard in a year of average stream flow and approximately 180,000,000 kilowatt hours of primary power in a year of minimum stream flow.

For the second step in the construction program, the development of reservoir capacity and of generating equipment in the Rowlesburg development may be considered favorable. It is estimated on the basis of prewar cost plus 40 per cent and from the information available from United States Geological Survey topographical maps that this development complete with generating and transmission equipment for 80,000 kilowatts will cost \$10,700,000. It will have an average operating head of 200 feet. It, with the State line and Blackwater developments, will generate 600,000,000 kilowatt hours of primary power in a year of average stream flow and 360,000,000 kilowatt hours of primary power in a year of minimum stream flow.

The third development would be the construction of a dam and installation of generating equipment at the Beaver Hole site. It will have an operating head of 245 feet. The estimated cost for lands, structures, 150,000 kilowatts of generating and transmitting equipment, is \$12,800,000. This development, and the State line, Blackwater, and Rowlesburg developments, will generate 950,000,000 kilowatt hours of primary power in a year of average stream flow and 600,000,000 kilowatt hours of primary power in a year of minimum stream flow.

The fourth development would be the construction of a dam and the installation of generating equipment at the site on the Cheat River below Muddy Creek. The estimated cost on the same basis as the above developments, with the exception of an installation of 120,000 kilowatts and an operating head of 240 feet, is \$13,000,000. This development and the four above developments will produce 1,250,000,000 kilowatt hours of primary power in a year of average stream flow and 780,000,000 kilowatt hours of primary power in a year of minimum stream flow.

The fifth step in the development of the Cheat River water powers would be the construction of the Big Sandy development. It would have a net operating head of 400 feet. The cost is estimated at \$6,000,000. It and the above developments will produce 1,350,000,000 kilowatt hours of primary power in a year of average stream flow and 870,000,000 kilowatt hours of primary power in a year of minimum stream flow.

As in the case of the Clarion River, the construction of water-power developments on the Cheat River, being a tributary of the Monongahela River, would, by its large storage capacity, assist in the improvement of navigation on the Monongahela and Ohio Rivers during their low-water flow, and also, to some extent, could be operated for the improvement of flood conditions.

CONCLUSION.

It is estimated in Table 5 that the total peak on the central station systems for the year 1927 would be 1,100,000 kilowatts, exclusive of requirements from steel companies and for railroad electrification. Adding to this 100,000 kilowatts for steel company requirements and 200,000 for railroad electrification will give a total estimated peak of 1,400,000 kilowatts. The present installed capacity of central station systems is 770,000 kilowatts. The present program of the central station companies will add some 300,000 kilowatts, which is only sufficient to replace the present inefficient equipment, whose operation should be discontinued. Of the 770,000 kilowatts, 170,000 should be considered as reserve capacity, leaving 600,000 kilowatts available for carrying peak load and which will take a portion of the estimated future peak of 1,400,000 kilowatts, leaving the requirement of new equipment to carry 800,000 kilowatts. With a peak of 1,400,000 kilowatts, the annual amount of power required is 6,000,000,000 kilowatt hours. The top 800,000 kilowatts of this peak, which is 57 per cent of 1,400,000 kilowatts, would require 35 per cent of the total power in kilowatt hours, or 2,100,000,000 kilowatt hours (based upon the typical load curve on Pl. 4).

This report recognizes that hydroelectric power which is available on the Clarion and Cheat Rivers and other proposed developments in the vicinity of western Pennsylvania, if operated in conjunction with existing steam-power systems, compare favorably at the present time with the production of power in additional steam plants of modern design. With increasing cost of labor and fuel, which will increase the cost of power at a faster rate in steam plants than it does in hydroelectric plants, future comparison will be more in favor of hydroelectric plants than at present. It is therefore recommended, in the provisions for additional generating equipment above that now contemplated in the present construction program of the central station companies, that serious consideration be given to the hydroelectric-power resources.

Looking toward furnishing the above-mentioned 800,000 kilowatts of capacity and the 2,100,000,000 kilowatts hours of power requirements, it may be said that the Clarion River developments discussed herein will furnish 300,000 kilowatts of power capacity and 650,000,000 kilowatt hours of power in a year of average stream flow. The total Cheat River developments will furnish 500,000 kilowatts of capacity and 1,350,000,000 kilowatt hours of power in a year of average stream flow, making a total for the developments on these two rivers of 800,000 kilowatts in capacity and 2,000,000,000 kilowatt hours in a year of average stream flow.

NOTE.—With the development of Cheat River power, the increased power requirement in the vicinity of Cumberland, Md., and Fairmont, W. Va., will draw upon this resource for some of its power.

There are other water powers in West Virginia and western Pennsylvania which may compare favorably with those considered in this report. Information, however, was not available which would warrant making any recommendations regarding them.

In a year of minimum stream flow, the developments on these two rivers would furnish only 1,290,000,000 kilowatt hours of power, which is 21½ per cent of the total required. It corresponds to 43½ per cent of the top portion of the load curve, or 610,000 kilowatts of power capacity. In other words, in a year of extreme low water, 190,000 kilowatts of reserved steam capacity would be called upon to make up the deficiency of water power which is available in a year of average stream flow.

Statements made in the report on power service for the Southern States, relative to the effect of interest charges on the cost of power, apply equally well in the district of western Pennsylvania and eastern Ohio, especially so, as to the advisable encouragement which should be given the development of water power. The high initial investments required for hydroelectric developments retard the construction of developments, which, when completed and placed under full load, would produce relatively cheaper power.

JOINT OPERATION OF STEAM AND HYDRO POWER SYSTEMS.

In the comparison of hydroelectric developments and modern steam power plants, the relatively large proportion of the total cost of steam power that consists of the fuel and labor charges has an important influence. This amounts to 56 per cent for a 55 per cent annual load factor and \$3 coal. In hydroelectric power the cost of power is nearly all made up of fixed expenses; that is, interest, taxes, and replacement charges, and the expense of operation of the plants amounts to only a small percentage. In a comparative study, a hydroelectric development may be favorable as long as it is operating under full load and there is a sale for all of its primary power, but in case of a slump in the power market, the fixed charges continue, whereas in the steam plant, the fuel and labor charges may be curtailed to the extent of the decrease in fuel and labor required under reduced power market conditions. In addition, this fixed charge on the hydroelectric development, even if, when distributed over the total primary power available, it is a reasonable amount, yet when distributed over the decreased amount of power actually sold may bring the cost of such power up to an exorbitant cost per kilowatt hour. It is therefore desirable that a hydroelectric plant, when built, be operated in conjunction with a steam power system of appreciable capacity, for during a slump in the power market or a falling off in the power demand, a saving may be effected in the operation of the system as a whole by an amount proportional to the value of the coal and labor that would have otherwise been expended in the steam plants had the demand kept up. The hydro plants on the other hand, whose annual costs remain unchanged during fluctuations in power output, are kept loaded up to full amount of the natural resource, which is wasted energy unless used.

A second value of combined operation is the free and more complete use of the water storage permitted by the insurance which the steam capacity furnishes. When it is known that there is

no steam capacity to fall back upon a more reserved use of the water-storage capacity is necessary during the approach of extreme low-water conditions and a less complete use of the water results. The supplemental steam capacity is therefore a guaranty of reliability of supply and of economical operation during conditions of quite opposite character, the one with a normal or even excess supply of available water power accompanied by a reduced power demand and the other a low supply of water power accompanied by a maximum power demand. There is also an additional advantage to combined operation, which has been mentioned elsewhere. The water power furnishes the peak portion of the load, and by so doing permits the operation of the steam capacity under a greater load factor. By increasing the load factor on the steam plants of the system the cost of steam power may be decreased by a greater amount per kilowatt hour than the corresponding increase in cost of the hydro power that results from the necessary overinstallation of only the equipment in the hydroelectric system in order to allow it to take the peak portion of the load. This requires only a small additional cost, comparatively, as the greater part of the investment is in the fixed structures whose costs are not increased by the overinstallation. The increase of the load factor on a steam system from 50 to 75 per cent may decrease the generating unit cost of power by 20 per cent for two-thirds of the total power, whereas the accompanying increase in the generating unit cost of the hydro power is only 13 per cent for one-third of the power. The hydroelectric developments possess a much greater value when operated in combination with steam than when operated alone as a separate system.

APPENDIX B-1.

ESTIMATED OUTPUT OF THE CENTRAL STATIONS OF WESTERN PENNSYLVANIA AND EASTERN OHIO—1913 TO 1918.

	In- stalled capa- city.	1913	1914	1915	1916	1917	1918
Duquesne Light Co.:	Kw.						
Brunots Island.....	119,500					431,480,000	476,561,400
Rankin.....	11,750						
Thirteenth Street.....	9,500						
Twentieth Street.....	6,400						
Glenwood.....	5,800						
Fallston.....	2,500						
Phipps.....	2,000						
	157,450	283,400,000	315,200,000	332,100,000	472,000,000	567,500,000	641,900,000
West Penn Power Co.:							
Windsor.....	40,000					8,178,500	118,573,200
Connellsville.....	60,000	89,572,800	118,283,800	142,222,900	202,305,400	263,299,500	210,529,100
Wheeling.....	6,500		14,528,200	10,925,500	31,888,700	35,873,200	17,908,700
Washington.....	1,500	5,282,800	6,273,100	6,809,300	7,255,000	8,279,600	4,230,400
Craigton.....	1,900	7,012,800	8,096,900	7,082,400	8,126,400	7,258,400	4,963,700
Butler.....	1,200	1,247,700	1,575,100	2,200,800	3,623,400	3,481,300	3,910,800
Brilliant.....			3,078,800	1,273,100	1,782,600	1,035,200	(1)
Ambridge.....		1,315,000	87,600	81,500	(1)	(1)	(1)
Kittanning Gas.....	480	1,497,700	1,518,800	2,341,600	1,659,200	1,966,600	968,400
Waynesburg Gas, isolated.....	400	347,400	478,100	482,700	543,100	697,200	886,800
Ligomer.....	200		194,100	292,000	300,500	390,300	412,700
Renfrew.....					3,338,400	4,433,200	
	112,150	108,276,200	154,116,500	173,661,700	260,622,700	331,393,000	362,378,800
Mahoning & Shenango Ry. & Light Co.:							
New Castle.....		5,382,000	357,000				
Ellwood— Steam.....		1,294,000	818,000	899,000	521,000	12,000	
Hydro.....	1,000	1,630,000	1,838,000	2,413,000	1,297,000	1,276,000	513,000
North Avenue.....	12,000	34,063,000	23,696,000	20,810,000	30,123,000	33,118,000	23,196,000
Lowellville.....	45,000	31,138,000	57,021,000	72,967,000	104,936,000	129,018,000	164,861,000
	58,000	73,477,000	83,730,000	97,089,000	136,887,000	163,424,000	188,572,000
American Gas & Elec- tric Co.:							
Windsor.....	250,000						
Wheeling.....	9,000	10,669,800	14,678,800	30,557,900	37,932,800	56,450,700	47,792,900
Canton.....	24,500	17,553,000	28,966,000	46,071,000	69,661,000	109,282,000	144,563,000
Newark.....	12,900	2,230,000	3,150,000	7,109,000	14,506,000	22,844,000	29,453,000
Ballville— Hydro.....	3,000	(1)	(1)	(1)	(1)	(1)	(1)
Steam.....	15,000					12,666,000	36,429,000
Steubenville.....	1,350				3,436,500	3,122,300	1,191,000
East Liverpool.....	7,000				15,879,000	28,736,400	20,573,100
	122,750	30,452,900	46,794,800	83,737,900	141,415,300	223,101,400	280,032,000
Henry L. Doherty & Co.:							
Warren.....	35,750	6,025,000	6,572,000	11,561,000	11,146,000	27,104,000	50,720,000
Alliance.....	6,000	2,471,000	2,692,000	3,644,000	5,084,000	9,941,000	12,212,000
Massillon.....	8,200	2,913,800	3,196,000	7,400,000	16,640,000	23,642,000	35,286,000
Mansfield.....	10,000				637,200	6,384,900	24,731,200
Lorain and Elyria.....	15,500		8,517,500	10,569,700	15,331,400	14,126,432	21,376,600
	75,450				50,038,600	81,098,332	144,332,800

¹ Shut down.

² Proportionate part of the capacity at the Windsor station.

³ Includes current received from Windsor station.

⁴ From Aug. 1, 1917, to Dec. 31, 1917.

⁵ Includes new 8,000-kilowatt unit added under Government contract.

APPENDIX B-1—Continued.

ESTIMATED OUTPUT OF THE CENTRAL STATIONS OF WESTERN PENNSYLVANIA AND EASTERN OHIO—1913 TO 1918.

	In- stalled capac- ity.	1913	1914	1915	1916	1917	1918
Cleveland Electric Il- luminating Co.: Lake Shore.....	Kw. 128,000	178,787,000	186,822,000	232,280,000	317,508,800	416,426,000	511,183,000
Canal.....	18,900	16,282,000	19,968,000	19,942,000	23,168,000	28,809,000	32,480,000
	146,900	192,069,000	206,810,000	252,202,000	340,671,000	444,735,000	543,663,000
City of Cleveland.....	16,000	.....	.....	32,897,000	50,008,000	57,276,000	67,482,000
Northern Ohio Traction Co.: Gorge.....	67,000	30,209,963	50,488,483	65,543,025	110,699,060	150,204,576	163,226,450
Canton.....	3,700	17,688,886	16,472,150	15,466,547	17,220,437	16,962,574	14,170,213
Hydro.....	2,175	.....	7,684,896	6,872,000	6,949,400	6,784,400	4,286,600
	72,875	47,898,819	74,595,529	87,882,172	134,638,897	173,941,550	181,682,263
Ohio Service Co.: Hydro.....	980	2,899,210	3,138,760	4,306,480	4,178,980	4,262,420	4,392,640
Steam.....	7,860	6,774,290	7,697,180	9,366,170	12,047,800	17,061,110	21,112,780
New.....	4,000	.....	.....	.....	.....	.....	.....
	12,840	9,663,500	10,835,940	13,672,650	16,226,780	21,323,530	25,505,420
Stark Electric Co.....	2,800	5,620,000	5,877,700	6,211,200	6,852,800	7,427,200	8,166,900

APPENDIX B-2.

MAXIMUM ANNUAL SYSTEM PEAK LOADS OF THE CENTRAL STATIONS OF WESTERN PENNSYLVANIA AND EASTERN OHIO FOR 1913 TO 1918.

	1913	1914	1915	1916	1917	1918
Duquesne Light Co.....	.....	.....	90,000	109,000	117,000	141,000
West Penn Power Co.....	.....	.....	.....	.....	165,058	78,380
Mahoning and Shenango Ry. & Light Co..	18,000	18,500	22,000	29,000	31,000	35,000
American Gas & Electric Co.: Windsor.....	.....	.....	.....	.....	.....	.....
Wheeling.....	3,070	3,725	9,000	9,700	10,000	10,550
Canton.....	6,929	8,598	12,325	20,337	34,600	34,000
Newark.....	600	1,050	2,400	4,000	5,100	7,300
Ballville— Hydro.....	.....	.....	.....	.....	.....	.....
Steam.....	.....	.....	.....	.....	8,000	10,000
Steubenville.....	.....	.....	.....	1,800	1,600	1,400
East Liverpool.....	.....	.....	.....	.....	.....	6,000
	.....	.....	.....	.....	.....	69,850
Henry L. Doherty & Co.: Warren.....	.....	.....	.....	.....	.....	(19,000)
Alliance.....	.....	843	1,270	2,100	2,500	3,300
Massillon.....	1,065	1,500	5,300	6,900	8,500	9,500
Mansfield.....	.....	.....	.....	300	5,700	7,500
Lorain and Elyria.....	.....	3,070	4,588	3,790	3,960	7,400
	.....	.....	.....	.....	.....	46,700
Cleveland Electric Illuminating Co.....	56,429	52,952	67,059	85,000	113,228	136,319
City of Cleveland.....	.....	.....	9,600	11,600	13,600	15,100
Northern Ohio Traction Co.....	.....	.....	.....	29,800	35,200	40,800
Ohio Service Co.....	.....	1,720	2,600	3,100	5,200	5,900
Stark Electric Co.....	1,760	2,040	2,280	2,460	2,530	2,460

¹ Including purchased power.

² Exclusive of purchased power.

APPENDIX B-3.

CENTRAL STATION PLANT OPERATION DURING 1919.

Maximum monthly power demand.

	January.	February.	March.	April.	May.
	<i>Kilowatts.</i>	<i>Kilowatts.</i>	<i>Kilowatts.</i>	<i>Kilowatts.</i>	<i>Kilowatts.</i>
Duquesne Light Co.....	132,000	130,000	115,000	.....	.....
West Penn Power Co.....	78,000	71,000	74,000	.....	.....
Mahoning and Shenango Light & Ry. Co.....	35,700	32,200	31,500	29,100	32,400
American Gas and Electric Co.:					
Wheeling.....	.....	.....	.....	.....	¹ 10,600
Canton.....	30,600	31,300	30,200	29,900	29,300
Newark.....	7,400	8,200	7,000	7,000	² 7,300
East Liverpool.....	6,400	.....	.....	.....	3,400
Henry L. Doherty & Co.:					
Warren.....	17,635	19,085	18,815	18,715	18,770
Alliance.....	3,800	2,500	2,800	2,800	2,500
Massillon.....	9,200	9,400	8,800	7,700	7,500
Lorain.....	.....	.....	.....	³ 6,740	.....
Mansfield.....	.....	.....	.....	³ 7,800	.....
Cleveland Electric Illuminating Co.....	122,576	117,836	112,937	113,863	108,776
Northern Ohio Traction and Light Co.....	39,600	40,400	40,600	38,400	36,500
Ohio Service Co.....	.....	.....	.....	⁴ 6,100	.....
Stark Electric Co.....	2,320	2,290	2,340	2,360	2,370

¹ To June 1.² From June 1 to June 15—10,100 kilowatts.³ Maximum for first 5 months.⁴ Maximum for first 6 months.*Monthly power output in kilowatt hours.*

	January.	February.	March.	April.	May.
Duquesne Light Co.....	.....	.....	.....	.....	.....
West Penn Power Co., Windsor plant.....	35,000,000	28,000,000	¹ 123,122,208	.....	.....
Mahoning and Shenango Light & Ry. Co.....	.....	.....	¹ 76,542,820	.....	.....
American Gas and Electric Co.:					
Wheeling.....	.....	.....	¹ 19,619,311	.....	.....
Canton.....	12,891,874	11,846,830	11,830,052	11,471,843	10,076,745
Newark.....	.....	.....	¹ 16,907,000	.....	.....
East Liverpool.....	2,145,900	1,191,300	1,308,800	1,127,200	1,081,900
Henry L. Doherty & Co.:					
Warren.....	.....	.....	² 27,989,180	.....	.....
Alliance.....	.....	.....	¹ 4,996,160	.....	.....
Massillon.....	3,446,240	3,070,165	2,785,552	1,853,066	.....
Lorain.....	.....	.....	18,093,800	.....	.....
Mansfield.....	.....	.....	¹ 14,274,300	.....	.....
Cleveland Electric Illuminating Co.....	.....	.....	¹ 221,375,370	.....	.....
Northern Ohio Traction & Light Co.....	.....	.....	¹ 85,455,759	.....	.....
Ohio Service Co.....	.....	.....	¹ 10,922,300	.....	.....

¹ Total for 5 months.² Includes current received from Windsor plant.³ Total for 4 months.

APPENDIX B-4.

ESTIMATED AMOUNT OF POWER-GENERATING EQUIPMENT IN ISOLATED POWER PLANTS.

[Exclusive of equipment owned by the larger steel companies.]

	Connected load.		Estimated increase to the peak load of central station systems.
	Total equipment.	Available to central station service in the next 5 to 7 years.	
State of Pennsylvania:	<i>Kilowatts.</i>	<i>Kilowatts.</i>	<i>Kilowatts.</i>
Duquesne Light Co. district.....	120,000	89,000	40,000
West Penn Power Co. district.....	280,000	166,000	75,000
Clarion River Power Co. ¹	85,200	21,000	8,000
Mahoning & Shenango Ry. & Light Co.....	21,000	15,000	6,000
State of Ohio:			
Mahoning & Shenango Ry. & Light Co.....	24,000	17,500	7,000
American Gas & Electric Co. districts—			
Canton.....	9,000	6,000	3,000
Newark.....	12,000	6,000	3,000
Henry L. Foherty & Co.—			
Warren.....	3,000	3,000	1,500
Alliance and Massillon.....	15,000	11,000	5,000
Lorain.....	10,000	7,000	3,500
Northern Ohio Traction & Light Co.....	40,000	27,500	12,500
Ohio Service Co.....	7,000	5,000	2,000
Cleveland Electric Illuminating Co.....	128,000	90,000	40,000
Total.....	704,200	464,000	206,500
Isolated power equipment in the major steel companies.....	800,000	320,000	180,000

¹ Incorporated but have no power-generating plant at present and are not furnishing power or light service.

APPENDIX B-5.

ESTIMATED POWER REQUIREMENTS FOR THE ELECTRIFICATION OF RAILROADS IN THE WESTERN PENNSYLVANIA AND EASTERN OHIO DISTRICT.

	Per annum.	
	Kilowatt hours.	Kilowatt.
Pennsylvania R. R.:		
Lines east—		
Pittsburgh Division.....	622,000,000	
Conemaugh.....		
Monongahela.....		
Lines west—		
Northwest system—		
Eastern Division.....	528,000,000	
Chesapeake & Potomac.....		
Easton & Amboy.....		
Southwest System—		
Pittsburgh.....		
	1,150,000,000	220,000
Baltimore & Ohio R. R.:		
Connellsville Division.....	300,000,000	60,000
Pittsburgh Division.....		
Grafton-Keyser Division.....		
Pittsburgh & Lake Erie:		
Youngstown.....	250,000,000	60,000
Connellsville.....		
Brownsville.....		
Bessemer & Lake Erie	125,000,000	35,000
Buffalo, Rochester & Pittsburgh	230,000,000	65,000
	2,405,000,000	505,000

APPENDIX C.

**Report to the Chief of Engineers, U. S. Army, dealing with
the Production, Transmission, and Distribution
of Mechanical and Electrical Power
in New England.**

**Submitted by MAJ. CARROLL H. SHAW, Engineers, U. S. Army,
Boston, Mass., April 21, 1919.**

OUTLINE OF NEW ENGLAND REPORT.

1. INTRODUCTION.
2. DISCUSSION.
3. POWER PRODUCTION.
4. FUTURE DEVELOPMENT.
5. CONCLUSIONS.



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NEW ENGLAND POWER REPORT.

INTRODUCTION.

1. Soon after the power section of the War Industries Board was organized, it became evident that a power shortage might be expected in the New England district. The industries, as well as utilities, had already suffered severely from the restrictive order of the Fuel Administration that went into effect early in February, 1918, whereby it became necessary to close down all manufacturing industries for stated periods, due to the inability of the railroads to handle the freight and coal that were offered to them, and also because of the lack of sufficient coal for the war-essential industries throughout the country.

2. A great deal of difficulty was experienced by nearly all of the utility companies in obtaining sufficient coal to continue the operation of their stations. This was, of course, the universal experience during that winter, but fortunately the situation did not become as critical in the New England States as with the utilities operating in Ohio and Pennsylvania, where in a number of cases actual shutdowns for several days took place because of lack of coal. None of the New England utilities, however, suffered actual cessation of operation from this difficulty.

3. One of the other serious features of the fuel problem that caused considerable operating difficulty was the poor quality of the fuel that was received. A few of the stations endeavored to utilize Nova Scotia coal, but found it entirely unsatisfactory when utilized under conditions where the standard bituminous coal of West Virginia had previously been used.

4. Early in the spring of 1918, a survey of all of the large utility companies was made by Maj. George F. Sever, Engineers, and his report indicated that while no serious shortage of power need be expected in the New England territory during 1918 if sufficient coal could be received, a very extensive construction program would be necessary in order to supply the requirements in 1919, 1920, and 1921. All of the isolated operating companies considered either that their installed equipment would be sufficient to handle all of their anticipated additional loads during 1918, or that the new equipment which they had arranged for would give them sufficient capacity. One exception to this situation was the New England Power Co., who were unable to determine until rather late in the spring upon a definite method of procedure to secure all of the additional capacity which they felt would be needed. A transmission line was arranged for from the new station of the Shore Line Electric Railway south of Norwich, Conn., to the substation of the New England

Power Co. at Millbury. The new 40,000-kilowatt steam turbine of the Narragansett Electric Lighting Co. at Providence was expected to add from 9,000 to 10,000 kilowatts to their available capacity. It was hoped that satisfactory arrangements could be made with the management of the New York, New Haven & Hartford Railroad Co., whereby a 10,000-kilowatt turbine which the New England Power Co. had on hand could be installed in the steam plant of the railroad company at Zylonite, and negotiations with this object in view were continued until, when they were finally abandoned, it was evident that it would be almost impossible to have the machine in operation as soon as necessary at the new location at Uxbridge, Mass.

5. Still further increases in load for 1918-19 appeared late in the spring, and negotiations were reopened between the New England Power Co. and the Edison Electric Illuminating Co. of Boston looking toward the interconnection of the systems of these companies by means of a high tension line of 25,000 kilowatts capacity. Although much delayed, the construction of a line having half the ultimate capacity was undertaken in September and was under way at the time of the signing of the armistice. The transformers had been ordered early in the spring, but, due to the fact that the final contract between the New England Power Co. and the Boston Edison Co. was not made until late in the summer, complete specifications for these transformers became available so late that they could not be completed for delivery until December, 1918.

6. The unavoidable delays that were experienced in the carrying on of the construction work of the several transmission lines and the power station at Uxbridge made it apparent early in October that it would be almost impossible to expect any of these additions to become available before 1919. The situation was somewhat relieved, however, by the fact that these same conditions also delayed the various industrial companies from calling for the full amount of the power which they had estimated would be required before December, 1918.

7. The maximum load on the New England power system in 1917 was approximately 68,000 kilowatts. It was estimated that the maximum load in 1918 would be very close to 100,000 kilowatts. This was never reached, however, due to the fact that the armistice interrupted intensive production in numerous plants, and also because several of the additional loads did not come on to the system until early this year (1919).

8. In August, 1918, Maj. Carroll H. Shaw, Engineers, was ordered to Boston as representative of the power section of the War Industries Board in the New England district. The principal effort in this territory was devoted to promoting and assisting the plans for the further extension of the generating capacity of the New England Power Co.; the Cumberland County Power & Light Co., at Portland, Me.; the Rutland Railway, Light & Power Co., at Rutland, Vt.; the Hortonia Power Co., at Rutland, Vt.; and also to making such investigations regarding war essential projects as were requested by the various departments of the War Industries Board at Washington.

9. The study of the conditions that existed throughout the territory made a large amount of general information available, which it seemed should be organized and put on record in such a manner that it could be made available for the War Department in case of

need within the next few years. The conditions in the manufacturing and utility industries in New England, as elsewhere, are changing rapidly, and it is doubtful if any data or estimates that can be submitted now can be of very great value beyond a period of five or six years.

10. Some of the data that have been used go back as far as 1869, and are very helpful as indicating the normal trend of development in the manufacturing industries. If the new data that have been prepared serve no better purpose, they will form a basis upon which future studies can be made and will help by indicating the tendencies of the development of power generation, transmission, and utilization.

DISCUSSION.

11. In the preparation of this report on the power situation in the six New England States it has been assumed that the increase in power requirements during the next five or six years will continue in the manner indicated by the records of previous years. For manufacturing industries the Census Bureau reports are available since 1869. For electric light and power and street railway companies, Census Bureau reports are available for 1907, 1912, and 1917. Detailed information has been secured from all of the street railway and electric light and power companies in New England covering their operations during 1915, 1916, 1917, and 1918. All of this information has been tabulated and correlated in such a manner that it has been found practical to make estimates for future conditions to cover a period of six years, including 1919-1924. These estimates have assumed a normal growth of each class of business, as indicated by the records of conditions that existed up to and including 1918.

12. Present records show the additions that are planned and are being made to hydroelectric and steam electric stations of the electric light and power companies for 1919, and rather close estimates can be made concerning additions in hydroelectric stations for 1920 and 1921. A majority of the hydroelectric developments can not be completed in less than a year and a half construction period, which means that any development undertaken in the spring of one year does not become available as a productive project until the beginning of the second following year. In the appendixes attached to this report this principle has been followed in making estimates of expected production from hydroelectric plants.

13. The annual increase in capacity of steam engines in manufacturing plants was smaller during 1909-1914 than during the preceding 15 years, and in this same period there has been no increase in the installed capacity of water wheels in these manufacturing plants. It has been assumed, however, that during the next few years there will be some increase in rating of wheels in manufacturing plants which will be brought about by the reconstruction of present installations and the utilization of more efficient wheels than those now installed.

14. In making an estimate of the probable total output of the electric light and power generating stations for the next five to seven years it has been assumed that the present rate of increase will continue. This will provide for the growth in load in industries, for

the taking over of the less efficient isolated industrial plants by the central-station systems, and for some increase in power for railroads. It is apparent that no complete relief from the present price of coal can be secured by the utilization of hydroelectric generating stations. Assuming the estimates for total output to be reasonably accurate, it has been found that the total of undeveloped hydroelectric projects that may be expected to be developed during the next five to seven years is about 80 per cent of the total requirements for this period. In other words, 70 per cent of all additional electric energy will be produced from steam generating stations. During 1918 the hydroelectric stations produced 39.7 per cent of the total output of the electric light and power stations. The probable increase in capacity in hydroelectric plants will in no wise keep pace with the increased requirements on these systems. In the following pages it will be shown that the installation of new steam and hydroelectric machinery and the construction of additional transmission lines, while involving tremendous investment, will enable the local distribution systems to have the requisite amount of electric energy available for their use at the lowest practicable cost.

15. The opportunities for conservation in the consumption of coal by electric light and power steam plants at the present time are not large. It will be shown that more than half of the kilowatt hours produced by such plants in New England are generated at a rate equal to or better than 2 pounds of coal per kilowatt hour, and that a large number of the stations generating electric energy at more than 2 pounds of coal per kilowatt hour are already interconnected with high tension transmission systems by which energy is now available at the 2-pound rate. It seems doubtful if it would be economically practicable to conserve more than 170,000 tons of coal a year of the 825,000 tons that are burned over and above the 2-pound rate (p. 24).

POWER PRODUCTION.

16. In obtaining the data that have been used in this report, it was found that the various reports of the Census Bureau on manufactures and on electric utilities contained very valuable information, and this has been used extensively. All figures between 1869 and 1914, inclusive, that are used are taken from these reports. In the tabulation of electric energy production by electric light and power stations for 1917, there were available not only the figures obtained by direct statements from the companies, but also the values as given by the census report for 1917. This gave a means of checking results, and the census figures were found to be 3.9 per cent lower than the total that had been secured from direct returns. This discrepancy is undoubtedly caused by a difference in classification of business. For example, the Vermont Marble Co. is not organized as a utility company, but since it retails electricity in Proctor, Vt., and wholesales nearly 6,000,000 kilowatt hours a year to the Rutland Railway, Light & Power Co., it has been classified as an electric light and power company in the direct returns, but was undoubtedly not so classified in the preparation of the census report.

17. The following table indicates the five groupings that were used in determining the total amount of energy produced, and the right-

hand column indicates the number of systems, companies, or organizations reported. Definite returns were available from practically all electric street railways, and for only two of the larger electric light and power companies was it necessary to make estimates for 1918.

TABLE A.—*Classification of business.*

Reference No.	Class.	Number of systems or companies represented.
1.....	Electric street railways.....	28
2.....	Electric light and power.....	193
3.....	Railroads—electrified section.....	1
4.....	Steam power plants—manufactures.....	25,000 to 30,000
5.....	Hydraulic power plants—manufactures.....	

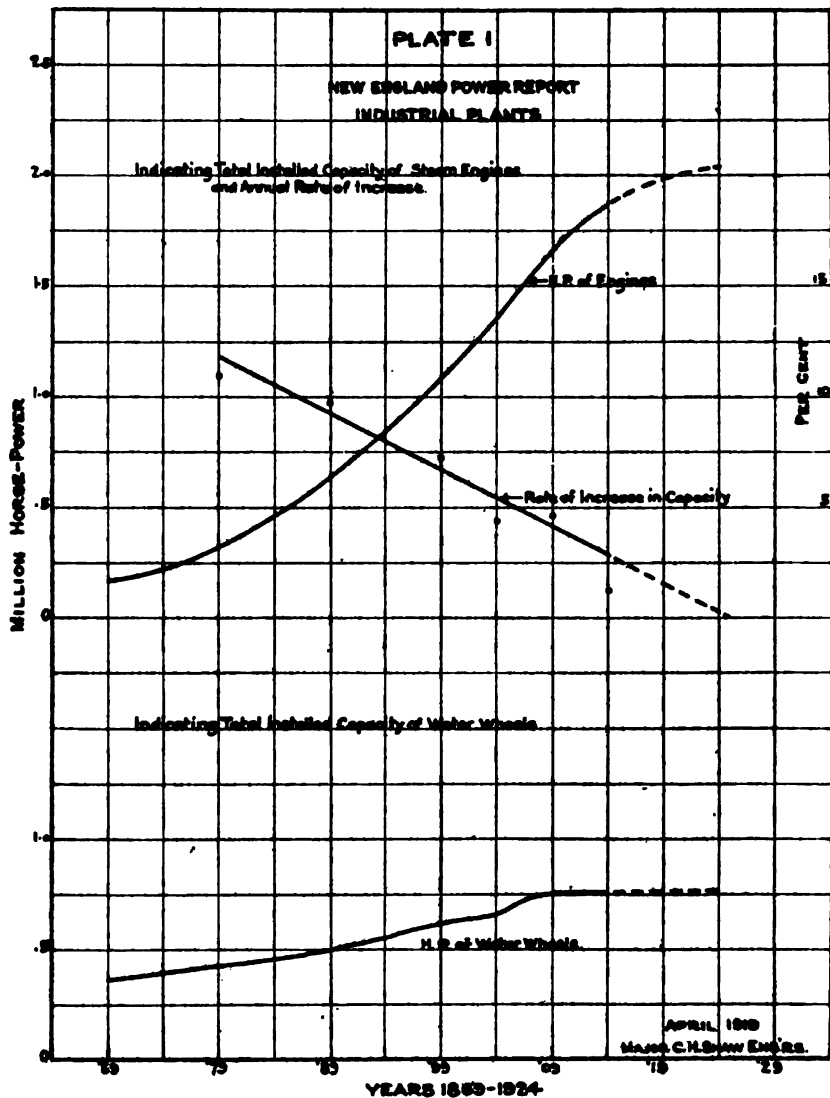
TABLE B.—*Kilowatt hours (or equivalent) generated—classified by business.*

Reference No.	1915	1916	1917	1918
1.....	629,762,000	677,769,000	709,808,000	610,984,000
2.....	1,320,723,800	1,685,494,000	1,909,924,000	2,174,309,000
3.....	101,881,000	85,690,000	87,889,000	77,811,000
4.....	2,485,000,000	2,630,000,000	2,560,000,000	2,580,000,000
5.....	1,490,000,000	1,490,000,000	1,490,000,000	1,490,000,000
Total.....	6,021,821,000	6,458,953,000	6,747,621,000	6,933,104,000
Annual per cent increase.....		7.3	4.5	2.7

18. As a direct basis of comparison of energy production, kilowatt hours have been used exclusively. Wherever the unit of "horsepower hours," as generated by water wheels or steam engines, has been converted to "kilowatt hours," a constant of 0.746 has been used, and by means of this comparison the above tabulation indicates in a comparative manner the total amount of energy that was produced by these various groupings of business. The figures for electric street railway, electric light and power companies, and electrified steam railroads have been determined by direct returns. The values for steam power plants and hydraulic power plants for manufacturing establishments were obtained from the census of manufactures from 1869 to 1914, inclusive. This census did not report the amount of energy produced, but contained complete data as to the rating of the power equipment that was installed in the manufacturing plants. This information is tabulated in Appendix No. 6 and is reduced to a graphical form in Plate No. 1.

19. From the curves in the upper section of Plate No. 1 it is seen that the total horsepower of the installed steam engines in manufacturing plants increased continually from 1869, but that the rate of increase showed a continual decline until in 1914 the average annual increase over the preceding five-year period was only 2.6 per cent, and indicated that by 1925, if no sooner, the increase would have stopped entirely. From this conclusion, and by making an assumption that the steam engines were operated on an annual utilization factor of 20 per cent, it was possible to arrive at the figures contained.

under reference No. 4. Similar data concerning water wheels installed in industrial plants were available from 1869 to 1914, and are represented graphically in the lower section of Plate No. 1. In this case, in arriving at the probable annual production of energy by these wheels an annual load factor of 30 per cent was used.



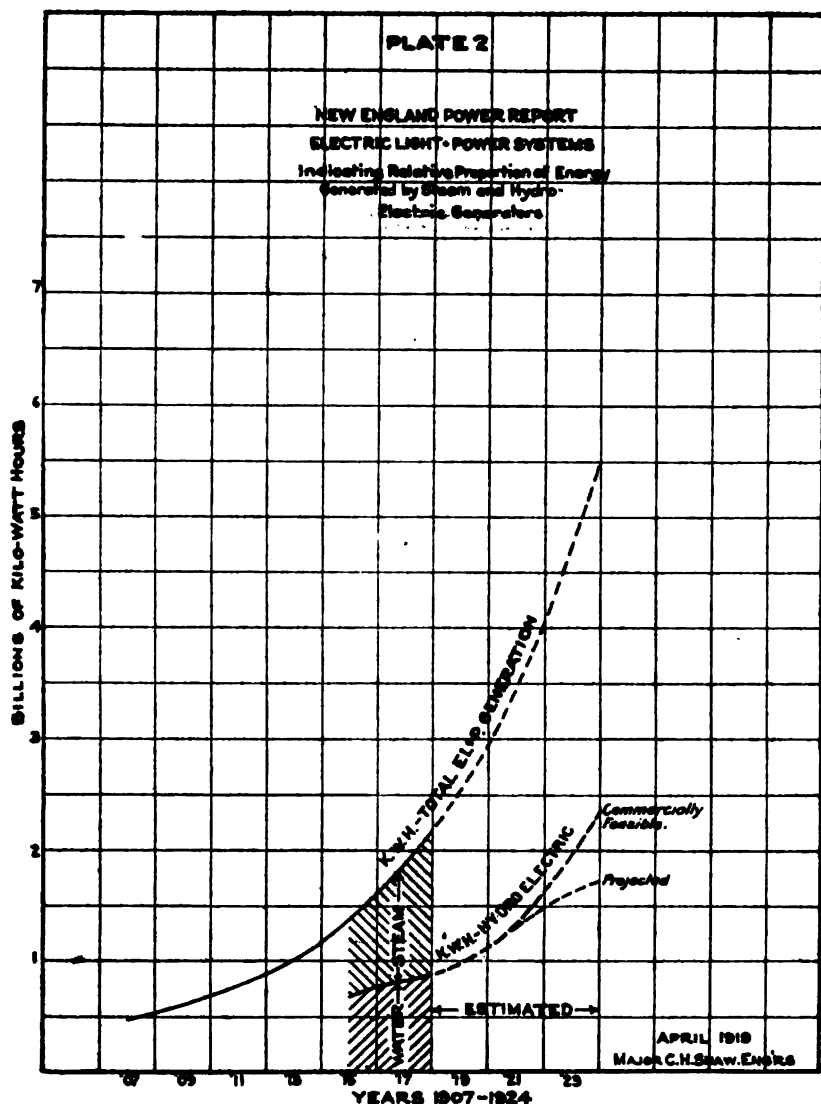
20. It should be noted that the total annual production of electric street railways decreased 99,000,000 kilowatt hours in 1918 over that produced in 1917.

21. The details of energy production for utilities as apportioned between steam and water power are shown in Appendix No. 1. The division of the energy output between steam and water power for electric light and power companies is given in Appendix No. 2. In

order to show the relative amounts of energy that were produced by steam and by water power, the figures that were utilized in the preparation of Table B have been regrouped, and in the following table this division is given.

TABLE C.—Kilowatt hours (or equivalent) generated—Classified by sources.

Source.	1915	1916	1917	1918
Steam.....	3,953,294,000	4,195,610,000	4,439,247,000	4,568,847,000
Water power.....	2,038,700,000	2,262,265,000	2,308,196,000	2,364,045,000
Internal combustion engines.....	827,000	1,078,000	178,000	212,000
Total.....	6,021,821,000	6,466,938,000	6,747,621,000	6,933,104,000



22. It will be seen that while the amount of energy produced by water power has increased less than 300,000,000 kilowatt hours during the past three years, the amount of energy produced by steam has increased more than 600,000,000 kilowatt hours. The item of internal-combustion engines refers to electric light and power stations only, and is given here so that the totals of Table B and Table C may check, and also to indicate the relatively insignificant amount of energy so produced.

23. By utilizing the census reports on electric light and power plants for 1907, 1912, and 1917, in conjunction with the reports for 1915, 1916, 1917, and 1918 that were obtained in this office, it has been possible to determine the normal increment in the output of the electric light and power stations during this period. With this information, it has been found practicable to estimate, by means of a graphical representation of the figures, the total amount of electrical energy that may be expected to be generated in the electric light and power stations during the following six years. This is shown in Plate No. 2, and in detail in Appendix No. 7-A. By means of the classification of energy production as between hydroelectric and steam electric, as contained in the direct returns, it is possible to indicate the relation between the two sources of energy production for 1915 to 1918 inclusive.

24. Information is also available indicating the probable additional installations of hydroelectric and steam electric units in electric light and power stations for the next two or three years. From this it has been possible to estimate the amount of hydroelectric energy that can be expected during each of these years. By deducting the expected production of hydroelectric energy from the expected total output of electric light and power stations, the amount of steam-generated energy that will be required has been determined.

25. In 1918 the utilization factor of the steam-generating capacity of electric light and power stations was 20.7 per cent. It is assumed that, with the increasing interconnection of large stations through electric transmission and distribution systems, this utilization factor will increase, and that by 1922 it will be approximately 23 per cent. This makes it possible to estimate the total additional capacity in steam turbines that will be required, in conjunction with hydroelectric units, to produce the total energy as indicated on Plate No. 2.

26. During 1919 there will probably be added 138,500 kilowatts to the steam-generating capacity in electric light and power stations. The schedule of these additions is shown in Appendix No. 8, which also indicate the projected increase in capacity in hydroelectric stations during 1919 to 1922 inclusive.

27. The generating capacity of the installed equipment in the various classes of business for 1915, 1916, 1917, and 1918 is given in the following table. For the purpose of comparison, the horsepower ratings of steam power plants and hydraulic power plants have been converted to kilowatts.

TABLE D.—*Installed generating capacity, kilowatts (or equivalent rating)—classified by business.*

Business.	1915	1916	1917	1918
Electric street railways.....	¹ 345,000	¹ 357,000	357,000	357,000
Electric light and power.....	¹ 720,000	¹ 820,000	918,000	¹ 1,030,000
Railroads—electrified section.....	85,000	35,000	35,000	35,000
Steam power plants—manufacturing.....	¹ 1,420,000	¹ 1,440,000	¹ 1,480,000	¹ 1,470,000
Hydraulic power—manufacturing.....	¹ 567,000	¹ 567,000	¹ 567,000	¹ 567,000
Total kilowatts.....	3,097,000	3,219,000	3,337,000	3,479,000

¹ Estimated.

28. In order to indicate the increase in capacity of all classes of power generating equipment, the following table has been prepared, giving the horsepower rating of the equipment installed and classified as to steam, hydro, and internal combustion. This grouping of capacity is arranged in a similar manner to the grouping of kilowatt hours output, the summary of which was indicated in Appendix No. 3. It should be noted that accurate figures are available in 1917 and 1918 for the more important classes in this table, with the exception of the data relating to manufactures. The last analysis of manufactures now available was dated 1914, so that the estimates for 1915 and 1918, inclusive, were obtained by projecting the values up to and including 1914.

TABLE E.—*Horsepower rating—Classified by sources.*

Source.	1915	1916	1917	1918
Steam:				
Street railways.....	¹ 449,000	¹ 466,000	466,000	466,000
Electric light and power.....	¹ 765,000	¹ 844,000	923,000	1,026,500
Railroads.....	50,000	50,000	50,000	50,000
Manufactures.....	¹ 1,900,000	¹ 1,980,000	¹ 1,955,000	¹ 1,975,000
Hydro:				
Street railways.....	45,000	45,000	45,000	45,000
Electric light and power.....	¹ 304,000	¹ 317,000	344,000	432,000
Manufactures.....	¹ 758,000	¹ 758,000	¹ 758,000	¹ 758,000
Internal combustion:				
Electric light and power.....	¹ 6,000	¹ 8,000	10,000	¹ 10,000
Manufactures.....	¹ 50,000	¹ 55,000	¹ 60,000	¹ 60,000
Total horsepower.....	4,327,000	4,473,000	4,611,000	4,820,500

¹ Estimated.

29. In making the estimates as to energy production in manufacturing plants as has already been noted, it has been necessary to make some assumption as to the probable utilization of the installed equipment. In order to indicate the basis upon which these estimates were made, the following table has been prepared showing the values that were available for 1917 and 1918, together with the estimates that had to be made where no accurate information could be procured. In determining upon 20 per cent as the utilization factor for steam-engine and turbine stations in manufacturing establishments, it is believed that the output of these units is in general very nearly equivalent to that of electric steam stations per unit of installed capacity. While the average load of the ordinary steam engine in an industrial plant may not be as uniform or may not be

equal to the total capacity of the machine to the extent that occurs frequently in electric light and power stations, it is also a fact that these isolated steam plants do not maintain or have available the reserve equipment that is ordinarily found in the utility plant. It has been assumed, therefore, that these factors offset each other to a considerable extent, and since the utilization factors for 1917 and 1918 give an average value of approximately 20 per cent, and since 1918 is higher than would normally be the case if the companies had been able to secure all of the capacity that they would have liked to have had as reserve, the estimate of 20 per cent is undoubtedly reasonable.

30. For hydraulic-power plants in manufacturing establishments, the utilization is considerably higher than for steam stations. A large amount of hydraulic power is used in such processes as "grinding" in paper mills, where the production continues for 24 hours a day every day in the week, and this factor is of so much importance that it is thought probable that the utilization of the water-wheel equipment in these stations will approach very nearly to that of the hydroelectric stations. Accurate data have been obtained from one of the larger paper mills indicating that the annual utilization factor of hydraulic equipment in one plant exceeds 91 per cent.

TABLE F.—Utilization of equipment—Tabulation of utilization factors.

	1917	1918
Steam engine and turbine stations:		
Street railways.....	24.4	21.0
Electric light and power.....	19.5	21.9
Railroads—electrified.....	25.7	25.4
Manufactures—all assumed.....		
Hydraulic power stations:		
Street railways.....	43.1	41.3
Electric light and power.....	33.2	32.6
Manufactures—all assumed.....		
Internal-combustion stations.....	(¹)	

¹ Unimportant.

31. After having estimated the future production in electric light and power stations, it is possible to make an estimate of the probable generating capacity that will be installed during 1919 through 1924, inclusive. In the following tabulation these estimates are given in units of 1,000 horsepower. It is probable that but little additional steam equipment will be put in by street railways in the immediate future, with the exception possibly of the new 25,000-kilowatt turbine that is to be installed by the Boston Elevated Railway Co. during 1919, and as it is very likely that an equal amount of obsolete generating equipment now carried on the records as installed capacity will be abandoned, it is assumed there will be no increase beyond 1919. The increase in the steam-turbine equipment for electric light and power stations has already been discussed, as has also the hydroelectric equipment for electric light and power stations. The principal electrified steam railroads are the Hoosic Tunnel section of the Boston & Albany Railroad and the division of the New York, New Haven & Hartford Railroad between New Haven, Conn., and New York City. The latter is now adding to its

generating equipment to provide for an increase in electric operation and to replace less efficient apparatus. The rate of coal consumption now exceeds 3 pounds of coal per kilowatt hour, and a portion (34 per cent in 1918) of the requirements is purchased from the New York Edison Co. under a rather high load factor, so that the resulting operating efficiency of the company's station is somewhat low. Other steam railroad electrifications may be undertaken within the next five years. The increases in the water-wheel capacity of manufacturing establishments have been assumed to be only the little that might be expected by the replacement of old, low-efficiency wheels by a modern, high-efficiency equipment. Apparently the electric light and power utility is the only class that is growing appreciably at the present time. The inherent advantages of electric power and the great economies of modern superpower stations indicate the probability that energy production will become more and more a specialized industry, not necessarily financially interrelated with the power transmission and distribution companies.

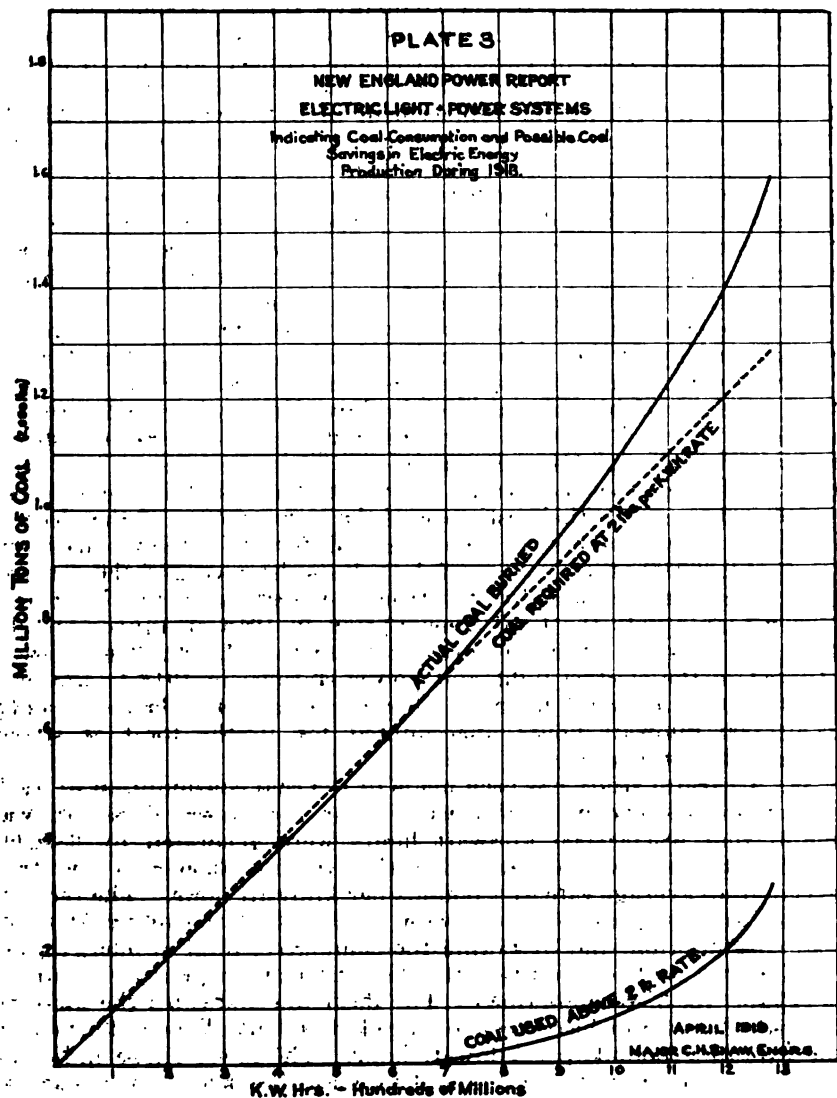
32. One of the most important factors in the production of steam-electric energy is the supply and utilization of coal. The United States Fuel Administration has estimated that during 1917 the total receipts of bituminous coal in New England were 26,300,000 net tons, of which 7,800,000 net tons were chargeable against steam railway operation. Of the remaining 18,500,000 tons, it has been estimated that the industrial manufacturing establishments took 13,500,000 tons. In their estimate of the consumption of the electric light and power plants in New England for 1917, they placed the total as 2,360,000 tons. A careful analysis, however, of the returns that have been received directly from the various electric light and power plants puts the total consumption in 1918 at approximately 1,610,000 tons. Accurate records indicate that 1,606,226 tons were utilized in the electric light and power stations in 1918 to produce 1,283,154,000 kilowatt hours. This leaves a net balance of only 28,327,000 kilowatt hours unaccounted for in the total of steam generated electric energy.

33. A careful study has been made of the coal consumption of each of the steam stations in the electric light and power class. It was found that 685,000,000 kilowatt hours were generated by 685,000 net tons of coal, which means that this amount of energy was produced at an average rate of 2 pounds per kilowatt hour. The records of the various steam stations were tabulated in the order of their coal consumption, and by taking the cumulative total of energy production and coal consumption the data used in preparing the curves on Plate No. 3 were obtained. The dash line indicates the amount of coal that would have been required if it had all been burned at the rate of 2 pounds per kilowatt hour. The lower curve indicates the difference between the 2-pound rate and the actual consumption, and shows that a maximum use of 325,000 tons occurred over and above this 2-pound rate in producing all of the electric light and power above the first 685,000,000 kilowatt hours during 1918.

34. A considerable portion of the coal that was burned above the 2-pound rate was used in steam-electric stations already having connection with the large transmission systems in this territory that were fed at other points by the more efficient steam plants, and for

this reason the utilization of this coal under these conditions may be looked upon as emergency or peak load consumption only.

35. A tabulation has been made (Appendix No. 10) in which is listed all of those power companies to whom 2 pounds per kilowatt hour steam energy was not available in any form over existing trans-



mission lines. These plants are shown with their 1918 rate of consumption, and the estimated possible coal rate at which energy should be generated for delivery to them from more efficient steam stations is given. From this, estimate was made of the possible saving in each of these plants and the total of 214,600 tons obtained. The company having the second largest coal consumption on this

list must be eliminated in making estimates of future conditions since the present coal consumption will be practically canceled after 1919 by the substitution of hydroelectric energy that is to be produced by a new station now in process of construction. Omitting this station, the largest single possible saving in one station amounts to only 14,200 tons, and the average for the 33 stations listed, excluding the one mentioned above, is 5,250 tons a year, or an aggregate of 192,800 tons.

36. In considering the possibilities of fuel conservation in central stations there are several matters that must be considered in conjunction with the possibility of reduction in the coal rate. Uniform and satisfactory electric service, especially for lighting and domestic use, requires that any possibility of interruption shall be avoided. Most of the electric light and power companies are more insistent upon the giving of reliable service than that their production costs shall be a minimum, and for this reason it will not be practical or desirable to expect an entire abandonment of the local steam stations in favor of energy produced by superpower stations entirely. The distribution systems in practically all of the cities are of such a character that it is impossible to separate the domestic consumer from the large power user, and in attempting to insure continuous service to the domestic consumers it is practically necessary to insure the same service and provide adequate capacity therefor to the large power users.

37. It is very probable that a large number of the individual public utility steam stations as noted in Appendix No. 10 could be closed down and energy purchased from neighboring higher efficiency stations without any attendant loss in reliability of service. This would be particularly true with those cities that are adjacent to large steam-generating stations, such as Boston, where the service would be obtained through underground conductors that would not be subject to the interruptions of overhead transmission lines.

38. The obvious conclusion from a careful study of the detailed coal data is that while there are many central stations operating at very poor economy, a very large per cent of the steam-generated energy is not produced with any material waste of coal.

39. One of the greatest opportunities for fuel conservation, aside from the direct substitution of hydro for steam power, is in the taking over by the central supply system of the less efficient of the isolated industrial steam plants. As indicated above, 13,500,000 tons of coal were consumed by industrial manufacturing establishments in 1917 (p. 179). Part of this was used for industrial processes and for heating, and figures are not available upon these items individually, but undoubtedly more than one-half of the total was consumed for power production. It is estimated that 2,500,000,000 kilowatt hours (p. 177) was generated by these manufacturing plants which would have required approximately 2,000,000 tons of coal if the power had been supplied from a central supply system, against possibly 7,000,000 tons actually used for power generation.

40. The opportunities for fuel conservation by electrification of steam railroads would offer tremendous possibilities. Adopting the estimate of the Fuel Administration that the coal consumption in

New England by the steam railroads in 1917 was 7,800,000 net tons, and assuming that by electrification of trunk lines 5,000,000 tons could be displaced, it is probable that a net saving of 3,000,000 tons could be made by electrification. This is possible on the assumption that electric energy could be delivered to the electric locomotives at a net coal consumption rate of 2 pounds per kilowatt hour, and that the saving of the present locomotive consumption would be 60 per cent.

41. The records of the New York, New Haven & Hartford Railroad indicate that at 2 pounds per kilowatt hour the saving for their express passenger service would be 59 per cent, for local passenger service 76 per cent, for fast-freight service 63 per cent, and for slow-freight service 58 per cent. While their station is not now operated at the 2-pound rate, it is proper to estimate that any future electrification will be supplied from superpower stations operating at considerably below 2 pounds per kilowatt hour, so that in using the figure of 2 pounds full account has been taken of the transmission and distribution losses.

FUTURE DEVELOPMENTS.

42. An estimate of the future developments in the power industry in New England is in effect an estimate of the future developments of the electric light and power stations. Plate No. 2 shows what may be expected in this direction and indicates that a tremendous expansion will be necessary in the electric light and power generating stations.

43. The cost of construction and the investment that will be necessary to provide for these developments must be given consideration. The cost of construction of hydroelectric plants is greatly in excess of the cost of steam electric stations; and as the more available locations for hydroelectric plants become developed, the cost of the necessary transmission lines makes the investments increasingly greater before the energy generated by them can be utilized.

44. The following table has been prepared, based upon the estimates contained in Appendix No. 5-C, to indicate the probable net investment that will be required to provide for these additional capacities. During the period just preceding the war it was possible to construct large steam electric power stations at from \$60 to \$70 per kilowatt, but during the period of the war this cost increased in one case of record to \$125 per kilowatt. In the following tabulation the investment is shown for the year preceding that in which it will become productive, and is, therefore, given for five years only, since the investment made in 1923 would be accounted for as additional installed capacity in 1924. It is estimated that hydroelectric developments will cost between \$200 and \$300 per kilowatt. It is assumed that the average for 1919 will be \$260 and thereafter \$250 a kilowatt. For steam electric stations it is estimated that the cost will be \$110 per kilowatt in 1919 and \$100 per kilowatt thereafter.

TABLE I.

Year in which investment is made.	Hydroelectric.			Steam turbine. ¹			Total increase.		
	1,000 kilowatts.	Cost per kilowatt.	Investment.	1,000 kilowatts.	Cost per kilowatt.	Investment.	1,000 kilowatts.	Cost per kilowatt.	Total Investment
1919.....	37	\$260	\$9,620,000	144	\$110	\$15,840,000	181	\$141	\$25,460,000
1920.....	57	250	14,250,000	100	100	10,000,000	157	154	24,250,000
1921.....	40	250	10,000,000	150	100	15,000,000	190	132	25,000,000
1922.....	38	280	9,500,000	300	100	30,000,000	338	117	39,500,000
1923.....	42	250	10,500,000	340	100	34,000,000	382	116	44,500,000
	214	252	53,870,000	1,084	101	104,840,000	1,248	128	158,710,000

¹ The above estimate does not include the cost of transmission lines or substations.

45. A study of the above table indicates that nearly \$11,000,000 a year will be absorbed by the construction of hydroelectric plants, and that more than \$20,000,000 per year will be required by steam stations.

46. For the hydroelectric developments the estimate does not necessarily include all of the transmission lines that will be required in some cases. If it becomes practicable to develop the few remaining large hydroelectric possibilities in the State of Maine, a transmission line of approximately 250 miles in length will be required before this energy can be delivered in any considerable quantities to the systems where it can be profitably utilized. The amount of this investment and its feasibility will be determined entirely by the market value of the energy that will be produced and by the cost of production at the plant. If this cost is so low that by the addition of the fixed charges and maintenance costs of the transmission line the total does not exceed the cost of a similar amount of energy produced by steam stations located at tidewater, and comparatively near the point of utilization, then these developments may be undertaken. At present the laws of the State of Maine prohibit the exportation of electric energy from that State (Revised Statutes, State of Maine, 1916, p. 985, ch. 60) and it is improbable that any large undertaking of this character would be considered while the attitude of the public is antagonistic to such a project, even though there might be found such technical flaws or means of exportation as to nullify the letter of the act.

47. An estimate has been made, details of which are included in Appendix No. 11, listing the undeveloped hydroelectric projects in New England that appear to be feasible; that is, that appear to offer either now or in the near future such opportunities for development as to make them financially profitable. The total of the additional kilowatts that will be available from these sources is 823,000, in addition to 30,000 kilowatts being installed in 1919 (Appendix 8-B), and it is estimated that these developments will produce 1,378,000,000 kilowatt hours annually plus 118,000,000 kilowatt hours produced by the 1919 developments (Appendix 7-B). The hydroelectric installations under consideration for development during the next five to seven years should have a total capacity of 234,000 kilowatts (Appendix 5-C), while the developments which appear commercially practicable at an early date have a capacity of 353,000 kilowatts as indicated above. The projected developments should produce

863,000,000 kilowatt hours annually (Appendix 7-B) and the commercially practicable developments 1,496,000,000 kilowatt hours. This output could probably be increased by the development of additional storage reservoirs at the headwaters of the various rivers where the hydroelectric developments are to be located, but would be obtained only by an additional investment not contemplated in the estimates in Table I.

48. In Appendix No. 12 an attempt has been made to set forth the maximum possible hydroelectric development that can be made, regardless of the profitability of the undertaking. These values have been taken from the special conservation and water-power reports of the States of Maine, New Hampshire, and Commonwealth of Massachusetts, from the conservation report of the State of Vermont, and from careful studies of each individual river development as contained in those and other available reports. The net difference between what is listed as feasible projects in Appendix No. 11 and the ultimate development in Appendix No. 12 amounts to 300,000 kilowatts and 700,000,000 kilowatt hours. It is very probable that there are included in the maximum possible developments some projects not included in the list of feasible developments, but the comparison indicates very pointedly that but little hydroelectric development can be expected after the completion of the stations that are included in Appendix No. 11.

49. What this means to the future development of New England as an industrial territory is this: that, except for this relatively small available increase in hydroelectric energy, the future increases must come from large steam-power stations. It has always been publicly assumed that the undeveloped water-power resources of this territory were practically unlimited, and that if properly developed and controlled they would be able to supplant all of the steam-electric stations that are now in existence. That this is far from the case is apparent by considering that the total classed as feasible hydroelectric developments, viz, 323,000 kilowatts, would be insufficient to provide for the increased total capacity that will be required during any two years between 1919 and 1922, and will be less than the estimated requirements for either 1923 or 1924.

50. If the growth in the public utility load continues at the present rate, which is approximately 15 per cent, further extensions of the high-tension transmission system between the large power stations and the manufacturing districts must be accomplished. At the present time there are but five steam generating stations that may be listed at 2 pounds per kilowatt hour units. The new station of the Turners Falls Power & Electric Co. at Chicopee and of the Shore Line Electric Railway below Norwich will undoubtedly be able to produce energy at the 2-pound rate under reasonable load factors. The station located at New Bedford is modern in every respect, and has possibilities for future development that are almost unlimited. The location of the station of the Narragansett Electric Lighting Co. at Providence is not entirely satisfactory, and limits the development of that station by the lack of suitable condensing water. The Bridgewater station of the Brockton Edison Co. should not be increased, although its present operating efficiency is relatively high. The station of the the Edison Electric Illuminating Co., of Boston,

is suitably located for large future developments. The station at Salem has operated at a rate of 2.01 pounds per kilowatt hour during 1918, and is classified as one of the efficient producing stations.

51. A study of the reports of the various companies in the western half of Connecticut indicates that a modern superpower station should be developed in that territory. Assuming a possible location intermediate between Bridgeport and New Haven, it is probable that a development of nearly 300,000 kilowatts will be required by 1924 if the additional increase in steam-electric energy that has been assumed occurs. A similar development of 300,000 kilowatts should be made along the northeastern shore of Massachusetts or in New Hampshire, possibly at Salem, Newburyport, or Portsmouth.

52. The total estimated additions in steam-electric stations as indicated in Appendix No. 5-C is 1,172,000 kilowatts. An increase of 60,000 kilowatts over and above the present contemplated additions at Boston, 60,000 addition at Providence, 75,000 at New Bedford, 70,000 at Norwich, and 75,000 at Chicopee would provide, together with the two new stations mentioned above, approximately 1,000,000 kilowatts, and these additions are approximately in those territories where a tremendous increase in electric energy consumption can be anticipated.

53. The increased capacity from the hydroelectric stations will become available in western Massachusetts, southern Vermont, and southern New Hampshire, and possibly in central Maine. The transmission lines that will be required to make the energy from these stations available will, with the exception of the Maine development, be entirely practicable. The present interconnected systems of the New England Power Co. and the Turners Falls Power & Electric Co. are very extensive. If the hydroelectric project at Windsor Locks were developed, a large capacity transmission line between Springfield, Mass., and Hartford, Conn., would be desirable. The erection of a large steam generating station adjacent to New Haven would call for the construction of extensive transmission lines to Bridgeport, Derby, Meriden, and thence to Waterbury and Hartford. The present transmission line of the New York, New Haven & Hartford Railroad between New York and New Haven is 25 cycles, and would probably not be interconnected electrically with the new system. It is probable that it would be found desirable to increase the capacity of the transmission lines extending from Ware through Palmer and Stafford Springs to Norwich, and an interconnection between Hartford and Stafford Springs would probably become desirable. If the New York, New Haven & Hartford Railroad should extend its electrification beyond New Haven, a transmission line from the new New Haven station connecting with the Norwich plant and thence to Providence would be necessary in order to provide energy for the use of the railroad. The estimate for the future station capacity has not contemplated providing for this load, but the location of the plants would be ideal for this development. An extension of the line now in operation between Providence and Fall River on to New Bedford and the connection of the New Bedford plant with the Bridgewater station, possibly through Taunton or Middleboro, would make it possible to take advantage of the full generating capacity of the New Bedford station with its compara-

tively low coal consumption per kilowatt hour. If the suggested plan of converting the transmission system of the Bay State Street Railway Co., extending from Quincy to Fall River, could be accomplished, it would add an important line between Taunton and Quincy, and if connected with the Boston Edison station would give unlimited capacity for growth in this territory. A map of the district showing the distribution system is attached.

54. The projected extension of the connection between the New England Power Co. and the Boston Edison Co., via Dedham, will probably be completed during 1919. The electrical development of Lowell, Lawrence, and Haverhill will require a tremendous expansion in electric generating equipment which will probably be accompanied by a connection between these cities and the new or enlarged superpower station located at either Salem, Newburyport, or Portsmouth, and with the system of the New England Power Co.

55. The construction of these transmission lines will probably take place as the business of the several companies increases, in a normal manner. The backbone of this distribution system now exists in the form of the transmission lines of the New England Power Co. and the Turners Falls Power & Electric Co. With the ultimate completion of this system, as outlined, it will make available for every manufacturing community in New England a reliable supply of energy that can be produced in modern efficient generating stations, either by hydroelectric or steam-electric equipment as the case may require.

56. It is probable that several comparatively inefficient steam stations will be kept ready for operation for the double purpose of maintaining the proper voltage regulation at the larger distributing centers and as insurance of the continuity of service.

57. With the development of this tremendous interconnected system very serious problems of system control and operation will have to be met. It is possible that the entire operation under normal conditions will have to be sectionalized, since the interconnection of a million to two million kilowatts into one system would undoubtedly offer such tremendous obstacles in the operation of the system under short-circuit conditions in case of line troubles that the cost of the equipment to handle these situations would be all out of proportion to the accompanying gains, but if the connections existed and were in regular operating condition, they would offer means for the localization of such troubles as might occur without the complete interruption of service to any one community.

58. The generation of such tremendous quantities of electrical energy from steam stations will mean the consumption of much larger quantities of fuel than has heretofore been contemplated. The increasing use of fuel oil in the operation of steam stations has become of considerable interest to the utility operators recently, and will undoubtedly become a very important factor in the construction and operation of steam stations. The possibilities of storage of oil without attendant depreciation and of the facility with which it may be handled make it particularly desirable for steam stations that may be operated only as reserve units.

59. The entire discussion of the power situation hinges upon what has been assumed as the future growth of the electric industry. Studies of the development of the electric light and power business

in individual cases indicate that the assumed increase as shown on Plate No. 2 is reasonable. If the total as indicated is not attained as rapidly as has been assumed, the increase, nevertheless, will be enormous, and will require an investment much larger in amount than has ever been contemplated in the past in the development of the electric industry. In making comparisons of the annual average increase in energy production, it should be borne in mind that, with the very recent extensive adoption of electric drive in the larger manufacturing plants, there has resulted a very noticeable decrease both in the total installed capacity and energy production as determined thereby. This is accounted for, not by the fact that there has probably been a decided falling off in the normal increase in business, but that utility companies are carrying more of their load and that the more efficient utilization of electric generating units as prime movers and the greater efficiency of the electric motor drive in mills has resulted in a temporary reduction of the normal increase of generating capacity that would have been required had mechanical drive been resorted to as heretofore.

CONCLUSIONS.

60. Except for slight increases in large isolated industrial plants, practically no increase in generating capacity may be expected in the future except for electric light and power companies. The efficiency of the superpower station in the generation of electric energy indicates clearly that this method of power production must prevail over former methods. The recent falling off in the growth of isolated plant power production indicates that the isolated plant is no longer to be the principal source of power for manufacturing industries.

61. Electric energy produced in modern, efficient generating stations, operated both by steam and by water power, delivering their products to high-tension electric transmission systems, and interconnected in such a manner that there exist numerous reliable power sources, apparently is to become the universal medium for manufacturing purposes.

62. The undeveloped hydroelectric resources of New England are extremely limited, and probably do not exceed 650,000 kilowatts, whereas the estimated increased generating capacity that will be required during the next five to seven years exceeds 1,400,000 kilowatts, and it is probable that it will not be commercially profitable to develop more than 350,000 kilowatts of the undeveloped 650,000 mentioned above. It is apparent, therefore, that by far the greater portion of the additions to generating capacity that will be required in this territory must be secured by the construction of steam-electric stations.

63. The investment that will be required to provide this additional generating equipment and the attendant transmission and distribution lines will be very large. There still remains a comparatively large number of small systems that should abandon their generating stations and secure their electric energy through the high-tension transmission lines that are connected to the most efficient generating stations.

64. The resources of any one community, district, or State should not be restricted for the use of the local inhabitants only. Laws designed to retain within the boundaries of any political unit the

energy that may be produced by hydroelectric stations located on its rivers can have no greater justification than would exist if another State should forbid the exportation of coal or oil or any other natural product that might be found within its boundaries.

65. New England with its six States of relatively small area, but with dense population, must be treated as one unit in the construction of power-generating stations and the transmission and distribution of electric energy. There is no surplus water power available for exportation beyond the confines of its territory, and it is probable that within the next decade it may be found advisable to import from Canada large quantities of energy generated on the St. Lawrence River and its tributaries.

CARROLL H. SHAW,

Major, Engineers, United States Army.

BOSTON, MASS., April 21, 1919.

APPENDIX C-1.

PUBLIC UTILITIES—SUMMARY OF ELECTRIC ENERGY PRODUCTION.

Classification.

Summary
No.

Class.

1. Street railway, steam (calendar year).
2. Street railway, hydro (calendar year).
3. Light and power, steam (calendar year).
4. Light and power, internal-combustion (calendar year).
5. Light and power, hydro (calendar year).
6. Light and power, unseparated (calendar year).
7. Light and power, steam (fiscal year).
8. Light and power, hydro (fiscal year).
9. Light and power, unseparated (fiscal year).
- E-1. Light and power, steam (calendar year) (estimated).
- E-2. Light and power, hydro (calendar year) (estimated).
- E-3. Light and power, unseparated (calendar year) (estimated).
- E-4. Light and power, steam (fiscal year) (estimated).
- E-5. Light and power, hydro (fiscal year) (estimated).
- E-6. Light and power, unseparated (fiscal year) (estimated).

Energy production—Kilowatt hours.

	1915	1916	1917	1918
1.....	618,763,407	665,867,269	698,027,295	599,555,289
2.....	10,999,289	11,901,760	11,780,807	11,428,553
3.....	688,876,963	828,556,234	1,074,968,166	1,285,382,432
4.....	527,189	1,078,178	177,820	212,000
5.....	491,240,622	673,356,298	774,710,418	837,915,351
6.....	2,304,510	80,145,647	3,693,516	3,410,554
7.....	19,775,446	15,691,779	19,304,184	21,798,644
8.....	5,087,615	7,786,208	8,541,202	7,811,352
9.....	67,973,008			
E-1.....	2,587,175	3,239,435	6,755,600	1,536,800
E-2.....	40,957,525	22,089,504	19,340,176	13,769,715
E-3.....	595,000	54,425,000	1,212,000	1,140,000
E-4.....	16,600	19,800	22,746	23,000
E-5.....	660,800	806,700	773,374	1,359,506
E-6.....	375,000	400,000	425,000	450,000
Total ¹	1,960,490,449	2,363,262,707	2,619,732,394	2,785,293,878

¹ Kilowatt hours generated by street railways and electric light and power stations.

APPENDIX C-2.

ELECTRIC LIGHT AND POWER STATIONS—ELECTRIC ENERGY PRODUCTION.

A. Steam stations—1,000 kilowatt hours.

	1915	1916	1917	1918
Total electric light and power generation ¹	1,320,728	1,685,494	1,909,924	2,174,309
Total of internal-combustion engines.....	827	1,078	178	212
Hydroelectric kilowatt hours (Appendix No. 2).....	1,319,901	1,684,416	1,909,746	2,174,097
Steam, kilowatt hours.....	567,701	760,363	806,415	862,616
Increase in kilowatt hours.....	752,200	924,053	1,103,331	1,311,481
Annual per cent increase.....		171.800	179,278	208,150
		22.8	19.4	18.9

¹ Does not include electric street railways or electrified steam railroad generating stations.

B. Hydroelectric stations—1,000 kilowatt hours.

Reference to summary.	1915	1916	1917	1918
5.....	491,240	673,356	774,711	837,915
6.....	1,304	33,000	2,000	1,410
8.....	5,038	7,736	8,541	7,311
9.....	28,000			
E-2.....	40,968	22,040	19,340	13,770
E-3.....	300	23,225	800	600
E-5.....	661	806	773	1,360
E-6.....	200	200	250	250
Total.....	567,701	760,363	806,415	862,616

Extract from Appendix No. 1.

APPENDIX C-3.

PUBLIC UTILITIES AND MANUFACTURES ENERGY PRODUCTION.

A. Steam stations (1,000 kilowatt hours or equivalent).

Source.	1915	1916	1917	1918
Street railways.....	618,763	665,867	698,027	599,555
Steam electric.....	752,200	924,063	1,108,331	1,311,481
Utilities.....	1,370,963	1,589,920	1,801,358	1,911,036
Railroads.....	101,331	86,690	87,889	77,811
Industrials.....	2,480,000	2,620,000	2,560,000	2,680,000
Total.....	3,962,264	4,195,610	4,439,247	4,568,847

B. Water power plants (1,000 kilowatt hours or equivalent).

Source.	1915	1916	1917	1918
Street railways.....	10,999	11,902	11,781	11,429
Hydroelectric.....	567,701	760,363	806,415	862,616
Utilities.....	578,700	772,265	818,196	874,045
Industrials.....	1,490,000	1,490,000	1,490,000	1,490,000
Total.....	2,068,700	2,382,265	2,306,196	2,344,045

APPENDIX C-4.

PUBLIC UTILITIES—SUMMARY OF POWER EQUIPMENT INSTALLED FROM CENSUS REPORT OF 1917.

[Horsepower.]

State.	Steam.		Water wheels.		Internal combustion.	
	Street railways.	Electric light and power.	Street railways.	Electric light and power.	Street railways.	Electric light and power.
Massachusetts.....	331,580	55,212	1,710	118,986	100	6,287
Maine.....	14,368	23,478	81,180	75,590		180
Connecticut.....	63,045	162,042	900	32,409		824
Rhode Island.....	55,306	131,008		3,738		1,125
New Hampshire.....	1,400	24,794	2,582	57,309		1,228
Vermont.....	200	17,285	8,194	56,425		80
Total.....	465,893	922,819	44,566	344,457	100	9,705
Kilowatts.....	326,000	645,600	31,200	241,000	70	6,800

One kilowatt of electric generating capacity is assumed to be equivalent to 1.43 horsepower for average census returns for three years.

APPENDIX C-5.

ELECTRIC LIGHT AND POWER STATION.

A. Total installed capacity of generators.

[Kilowatts.]

State.	1907	1912	1917
Massachusetts.....	135,924	252,722	478,983
Maine.....	39,290	58,757	63,242
Connecticut.....	39,363	77,655	152,649
Rhode Island.....	21,040	28,609	106,017
New Hampshire.....	21,917	57,768	68,660
Vermont.....	21,854	29,468	51,761
Total horsepower.....	289,388	514,889	918,152
Total kilowatts.....	290,000	515,000	918,000
Increase.....		225,000	408,000
Average annual per cent increase.....		15.5	15.6

B. Detail of installed generating capacity.

1. STEAM ENGINES AND TURBINES.

[Horsepower.]

State.	1907	1912	1917
Massachusetts.....	170,457	323,128	555,212
Maine.....	18,114	19,610	22,478
Connecticut.....	37,492	89,372	162,642
Rhode Island.....	24,723	46,984	131,008
New Hampshire.....	20,265	26,386	34,794
Vermont.....	9,889	14,996	17,286
Total horsepower.....	280,940	519,426	922,319
Total kilowatts.....	196,000	363,000	645,000
Increase kilowatts.....		167,000	282,000
Average annual per cent increase.....		17	15.6

(A) FROM CENSUS OF 1917.

	Horsepower.	Kilowatts.	Average per cent increase.
1907.....	281,000	197,000	.....
1912.....	519,000	363,000	17.0
1917.....	923,000	645,000	15.6

(B) ESTIMATE INSTALLED.

1915.....	761,000	533,000	.....
1916.....	842,000	590,000	.....
1917.....	923,000	645,000	.....
1918.....	1,026,500	717,500	11.1

B. Detail of installed generating capacity.

2. WATER WHEELS.

[Horsepower.]

State.	1907	1912	1917	1918
Massachusetts.....	16,781	24,480	118,986	157,727
Maine.....	39,796	69,988	76,590	128,760
Connecticut.....	18,045	19,484	32,409	32,600
Rhode Island.....	2,268	2,440	3,788	2,026
New Hampshire.....	25,404	56,987	57,809	57,156
Vermont.....	28,472	35,272	56,426	78,239
Total horsepower.....	130,731	208,501	344,457	451,508
Total kilowatts.....	91,600	148,500	241,000	316,000
Increase.....		58,900	96,500	76,000
Average annual per cent increase.....		11.8	13.1	8.1

(A) FROM CENSUS OF 1917.

	Horse-power.	Kilowatts.	Average per cent increase,
1907.....	130,700	91,600	-----
1912.....	208,500	148,500	11.8
1917.....	344,500	241,000	13.1

(B) ESTIMATE INSTALLED.

1915.....	304,000	208,000	-----
1916.....	317,000	223,000	-----
1917.....	344,500	241,000	-----
1918.....	451,500	316,000	81.1

C. Estimate of annual increases of generating capacity.

[Kilowatts.]

	Hydro-electric.	Steam electric.	Total.
1919—First.....	30,000	138,500	168,500
1920—Second.....	37,000	144,000	181,000
1921—Third.....	57,000	100,000	157,000
1922—Fourth.....	40,000	150,000	190,000
1923—Fifth.....	35,000	300,000	335,000
1924—Sixth.....	35,000	340,000	375,000
Total.....	224,000	1,172,500	1,406,500

APPENDIX C-6.

MANUFACTURES—INSTALLED POWER EQUIPMENT.

A. Steam engines and turbines.

(A) FROM CENSUS OF 1915.

Year.	Installed horsepower.	Annual per cent increase.
1899.....	153,000	-----
1879.....	820,000	10.9
1889.....	684,000	9.8
1899.....	1,099,000	7.3
1904.....	1,848,000	4.4
1909.....	1,689,000	4.7
1914.....	1,874,000	2.6

(B) ESTIMATE INSTALLED.¹

	Horsepower.	Kilowatts.
1915.....	1,800,000	1,420,000
1916.....	1,880,000	1,440,000
1917.....	1,855,000	1,400,000
1918.....	1,975,000	1,470,000

¹ Horsepower $\times .746$ = Kilowatts.*B. Water wheels.*

(A) FROM CENSUS OF 1915.

Year.	Installed horsepower.	Annual per cent increase.
1909.....	362,000	.....
1909.....	423,000	1.7
1909.....	497,000	1.3
1909.....	619,000	2.5
1904.....	659,000	1.3
1909.....	757,300	3.0
1914.....	757,600	0.0

(B) ESTIMATE INSTALLED.

Year.	Horsepower.	Kilowatts.
1915.....	758,000	567,000
1916.....	758,000	567,000
1917.....	758,000	567,000
1918.....	758,000	567,000

APPENDIX C-7.

ELECTRIC LIGHT AND POWER STATIONS—ENERGY PRODUCTION.

*A. Total electric energy production in million kilowatt hours.*STEAM AND WATER POWER.¹

Year.	Census, 1917.	Questionnaire.	Computation.	Values used.	Yearly increase.	
					Kilowatt hours.	Per cent.
1907.....	473	.....	.....	473	.....	.....
1908.....	530	530	57	12.0
1909.....	598	598	68	12.8
1910.....	675	675	77	12.8
1911.....	764	764	89	13.2
1912.....	865	.....	.....	865	101	13.2
1913.....	1,009	1,009	144	16.6
1914.....	1,181	1,181	172	17.0
1915.....	1,321	1,376	1,376	195	16.5
1916.....	1,685	1,600	1,600	224	16.2
1917.....	1,836	1,910	1,880	1,880	280	16.2
1918.....	2,174	2,164	2,164	304	16.3
1919.....	2,521	2,521	357	16.5
1920.....	2,941	2,941	420	16.6
1921.....	3,435	3,435	494	16.8
1922.....	4,015	4,015	580	16.8
1923.....	4,711	4,711	696	17.3
1924.....	5,517	5,517	806	17.1

¹ Small amount of internal combustion engine generated energy also included.

B. Normal increase during next six years.

KILOWATT HOURS.

	Hydroelectric.	Steam-electric.	Total.
1919—First.....	118,000,000	239,000,000	357,000,000
1920—Second.....	136,000,000	284,000,000	420,000,000
1921—Third.....	203,000,000	291,000,000	494,000,000
1922—Fourth.....	173,000,000	407,000,000	580,000,000
1923—Fifth.....	107,000,000	589,000,000	696,000,000
1924—Sixth.....	126,000,000	690,000,000	806,000,000
6-year increase.....	863,000,000	2,490,000,000	3,353,000,000

APPENDIX C-8.

ELECTRIC LIGHT AND POWER STATIONS—GENERATING EQUIPMENT INSTALLED AND TO BE INSTALLED.*A. Steam turbine units.*

IN 1918.

Location of station.	Horse-power.	Kilowatts.
Providence.....	57,000	40,000
Bridgeport.....	10,700	7,500
Hartford.....	14,800	10,000
Chicopee.....	21,800	15,000
Total.....	103,500	72,500

IN 1919.

Boston.....	96,000	60,000
Millbury.....	14,800	10,000
Norwich.....	28,600	20,000
New Bedford.....	21,800	15,000
Chicopee.....	21,500	15,000
Pittsfield.....	3,600	2,500
Worcester.....	22,900	16,000
Total.....	198,400	138,500

B. Hydroelectric units.

CLASSIFIED BY YEAR IN WHICH EQUIPMENT BECOMES AVAILABLE.

[Horsepower.]

	1919	1920	1921	1922
Turners Falls.....			10,000	10,000
Central Maine.....	3,600		10,000	5,000
Connecticut Light Power.....		26,000	9,000	
New England Power Co.....	3,000	12,000	28,000	34,000
Hortonville.....	3,600		3,000	5,000
Rumford Falls.....	18,000	9,000	9,000	
Cumberland County.....			16,000	
Millford Co.....	1,400	3,000	2,000	2,000
Manchester.....	3,000	1,200		
Norwich.....				
Total horsepower.....	42,600	53,200	83,000	56,000
Total kilowatts of electricity generated.....	30,000	37,000	57,000	40,000

APPENDIX C-9.

ELECTRIC LIGHT AND POWER STATIONS—DETERMINATION OF NECESSARY ANNUAL INCREASE IN STEAM GENERATING CAPACITY.

[References—Appendix No. 7-A; Appendix No. 8-B.]

Annual production of hydroelectric energy.

Year.	Horse-power.	Kilowatts.	Per cent utilization.	Kilowatt hours.
1917.....	344,500	241,000	¹ 38.2	806,415,000
1918.....	451,500	316,000	¹ 31.1	863,616,000
1919.....	494,100	346,000	² 32	971,000,000
1920.....	547,300	388,000	² 33	1,107,000,000
1921.....	629,300	440,000	² 34	1,310,000,000
1922.....	686,300	480,000	² 35	1,488,000,000
1923.....	740,000	518,000	² 35	1,590,000,000
1924.....	800,000	560,000	² 35	1,716,000,000

¹ Actual.² Assumed.

In the following table the hydroelectric production is subtracted from the estimated total production to determine steam-electric production that will be required, and the necessary steam-electric generating capacity is determined therefrom.

1,000,000 KILOWATT HOURS.

	1919	1920	1921	1922	1923	1924
<i>Kilowatt hours.</i>						
estimated total from all sources.....	2,521	2,941	3,435	4,015	4,711	5,517
<i>Hydroelectric.</i>						
Estimated kilowatt hours.....	971	1,107	1,310	1,483	1,590	1,716
<i>Steam.</i>						
Kilowatt hours.....	1,550	1,834	2,125	2,532	3,121	3,801
Increase in steam each year.....	239	284	291	407	589	680
Per cent increase.....	13.2	17.7	15.8	19.1	23.3	21.8

STEAM ELECTRIC.

<i>Kilowatt hours.</i>						
Estimated total.....	1,550	1,834	2,125	3,532	3,121	3,801
Assumed utilization.....	0.207	0.21	0.22	0.23	0.23	0.23
1,000 kilowatts required.....	866	1,000	1,100	1,250	1,550	1,890
Yearly increase in 1,000 kilowatts.....	139	144	100	150	300	340
Total increase.....	139	283	383	533	833	1,173
Per cent increase.....	19.4	16.8	10.6	13.6	24.0	21.9

APPENDIX C-10.

TABULATION INDICATING POSSIBLE COAL SAVING TO BE SECURED BY MEANS OF FURTHER INTERCONNECTION OF ELECTRIC DISTRIBUTION SYSTEMS WITH LARGE POWER SYSTEMS.

Question- naire No.	District.	Pounds per kilowatt hour.		1918, tons now.	Tons then.	Net saving.
		Present.	Possible.			
17	Cambridge.....	2.25	1.90	29,800	25,200	4,600
18	Lowell.....	2.31	2.00	35,100	30,400	4,700
36	Hartford.....	2.37	2.00	91,100	76,900	14,200
34	Bridgeport.....	2.47	2.00	115,000	93,200	21,800
	New Haven.....	2.69	2.00	14,200	10,600	3,600
164	Newburyport.....	2.70	2.00	26,800	19,800	7,000
33	Stamford.....	2.77	2.00	28,300	20,400	7,900
41	Portsmouth.....	2.80	2.00	8,400	2,400	1,000
143	Gloucester.....	2.86	2.00	25,000	17,600	7,600
24	Holyoke municipal.....	3.06	2.00	26,200	16,500	8,700
105	Derby.....	3.08	2.00	12,300	8,000	4,300
181	Taunton municipal.....	3.10	2.00	15,800	10,200	5,600
26	Haverhill.....	3.10	2.00	18,000	11,600	6,400
30	Pittsfield.....	3.32	2.00	7,900	4,800	3,100
42	Manchester.....	3.34	2.00	26,500	15,900	10,600
31	Lynn.....	3.43	1.90	8,800	5,100	3,700
173	Quincy.....	3.50	2.00	18,300	10,600	7,800
35	New London.....	3.51	2.00	5,600	3,100	2,400
106	Groton municipal.....	3.61	2.00	92,700	51,300	41,400
113	Waterbury.....	3.88	1.95	2,200	1,100	1,100
137	East Braintree municipal.....	4.02	2.00	12,000	6,000	6,000
114	Norwich municipal.....	4.06	2.00	6,300	3,100	3,200
131	Beverly.....	4.07	2.00	18,600	9,100	9,500
111	Malden.....	4.60	2.00	9,000	3,900	5,100
104	Danbury.....	4.62	1.95	11,900	5,200	6,700
139	Weymouth.....	4.87	2.00	2,700	1,100	1,600
151	Hudson municipal.....	5.06	2.00	3,300	1,300	2,000
175	Reading municipal.....	5.68	2.00	8,500	1,200	2,300
135	Concord municipal.....	5.90	2.00	3,300	1,100	2,200
168	Marblehead municipal.....	6.11	2.00	1,600	600	1,000
149	Holyoke water.....	6.27	2.00	3,300	1,000	2,300
153	Ipswich municipal.....	8.00	2.00	5,000	1,300	3,700
130	Lawrence.....	30.2	3.00	1,600	200	1,400
45	Leicester.....					
				684,200	469,600	214,600

APPENDIX C-11.

[Compiled by Maj. George P. Sever, Engineers, U. S. A.]

TABULATION OF UNDEVELOPED HYDRO-ELECTRIC PROJECTS THAT APPEAR TO BE FEASIBLE.

Summary.

State.	Added kilowatts.	Added kilo- watt hours when completed.
Massachusetts.....	62,500	271,000,000
Maine.....	116,400	633,000,000
Connecticut.....	44,000	138,000,000
New Hampshire.....	37,500	120,000,000
Vermont.....	63,600	216,000,000
	323,000	1,378,000,000

MASSACHUSETTS.

River.	Added kilowatts.	Added kilowatt hours when completed.
Deerfield.....	23,500	138,000,000
Westfield.....	25,000	68,000,000
Millers.....	12,000	56,000,000
Nashua.....	2,000	9,000,000
	62,500	271,000,000

MAINE.

Kennebec.....	82,000	483,000,000
Androscoggin.....	19,800	197,000,000
Saco.....	9,000	24,000,000
Penobscot.....	5,600	29,000,000
	116,400	633,000,000

CONNECTICUT.

Housatonic.....	24,000	75,000,000
Connecticut.....	20,000	63,000,000
	44,000	138,000,000

NEW HAMPSHIRE.

Contocook.....	10,000	30,000,000
Connecticut.....	8,500	20,000,000
Androscoggin.....	1,000	4,000,000
	18,000	66,000,000
	37,500	120,000,000

VERMONT.

Connecticut.....	24,000	85,000,000
Deerfield.....	21,000	71,000,000
Otter Creek.....	4,950	30,000,000
East Creek.....	1,950	7,000,000
Middlebury.....	4,000	10,000,000
Timmonh.....	2,500	8,000,000
Winooski.....	4,200	5,000,000
	62,600	216,000,000

APPENDIX C-12.

[Compiled by Maj. George F. Fever, Engineers, United States Army.]

TABULATION OF UNDEVELOPED HYDROELECTRIC PROJECTS OF WHICH RECORDS ARE AVAILABLE.*Summary.*

State.	Available kilowatts.	Kilowatt hours.
Massachusetts.....	70,438	299,779,000
Maine.....	258,120	905,500,000
Connecticut.....	46,000	145,000,000
New Hampshire.....	155,742	494,019,000
Vermont.....	71,459	240,914,040
	601,759	2,085,212,040

MASSACHUSETTS.

River.	Available kilowatts.	Kilowatt hours.
Millers.....	12,000	56,000,000
Deerfield.....	26,500	97,000,000
Vermont Storage.....		41,000,000
Chicopee.....	8,836	13,600,000
Westfield.....	26,000	68,374,000
Farmington.....	3,860	13,626,000
Quinebaug.....	202	885,000
Nashua.....	2,000	9,600,000
	70,438	299,779,000

MAINE.

Kennebec.....	133,000	467,000,000
Androscoggin.....	23,000	98,300,000
Saco.....	14,000	49,100,000
Penobscot.....	80,600	282,000,000
Presumpscot.....	2,620	9,200,000
	258,120	905,600,000

CONNECTICUT.

Quinebaug.....	2,000	7,000,000
Housatonic.....	24,000	76,000,000
Connecticut.....	20,000	63,000,000
	46,000	145,000,000

NEW HAMPSHIRE.

Merrimack.....	18,680	50,420,000
Contoocook.....	23,587	63,194,000
Blackwater.....	8,156	20,406,000
Connecticut.....	84,420	286,000,000
Androscoggin.....	21,000	74,000,000
	155,742	494,019,000

VERMONT.

Otter Creek.....	4,960	30,000,000
Vermont Marble Co.....	(1)	10,000,000
Winocaki.....	4,200	7,000,000
Tinnmouth Branch.....	2,500	8,000,000
Middlebury.....	4,000	10,000,000
East Creek, Mendon.....	1,960	7,250,000
Green River.....	2,600	8,000,000
Ithiel Falls.....	600	1,000,000
Moose River.....	2,610	1,921,000
Passumpsic.....	386	265,000
Ompompansoe.....	74	8,040
Black.....	1,370	1,080,000
Ottawaquebee.....	1,520	423,000
Ballows Falls.....	24,000	85,000,000
Deerfield.....	21,000	71,000,000
	71,469	240,914,040

1 None.

APPENDIX C-18.

[Compiled by Maj. George F. Sever, Engineers, United States Army.]

ELECTRIC LIGHT AND POWER STATIONS—RATING OF INSTALLED WATER WHEELS, 1918.

Summary.

State.	Rated horsepower.	State.	Rated horsepower.
Massachusetts.....	157,727	New Hampshire.....	57,156
Maine.....	128,760	Vermont.....	78,289
Connecticut.....	32,600		
Rhode Island.....	2,026		451,508

MASSACHUSETTS.

Company.	Location.	Rated horsepower.	River.
Athol Gas & Electric Co.....	Athol.....	2,200	Millers.
Central Massachusetts Electric Co.....	Palmer.....	1,200	Quaboag.
Charlemont Electric Light & Power Co.....	Charlemont.....	100	Deerfield.
Chester Electric Light Co.....	Chester.....	52	Northfield.
Fitchburg Gas & Electric Co.....	Fitchburg.....	500	Nashua.
Greenfield Electric Light & Power Co.....	Greenfield.....	4,200	Green.
Holyoke Municipal Gas & Electric Co.....	Holyoke.....	1,040	Connecticut.
Holyoke Water Power Co.....	do.....	2,085	Do.
Huntington Electric Light Co.....	Huntington.....	40	Northfield.
Lawrence Gas Co.....	Lawrence.....	3,175	Merrimack.
Lee Electric Co.....	Lee.....	120	Housatonic.
Metropolitan Washusett & Sudbury Board (Boston).....	Wachusett.....	4,800	Wachusett Reservoir.
Middleboro Gas & Electric Plant.....	Sudbury.....	1,600	Sudbury.
Monument Hills.....	Middleboro.....	159	Taunton.
New England Power Co.....	Housatonic.....	2,240	Housatonic.
North Dana Electric Light Co.....	North Dana.....	51,800	Deerfield.
Shelburne Falls & Colerain Street Railway Co.....	Shelburne Falls.....	75	H. B. Swift.
Strathmore Paper Co.....	Worcester.....	200	Deerfield.
Turners Falls Power & Electric Co.....	Turners Falls No. 1 Plant, Montague City.....	3,000	Westfield.
	Hampden.....	60,000	Connecticut.
United Electric Light Co.....	Springfield.....	7,200	Chicopee.
Weymouth Light & Power Co.....	E. Weymouth.....	6,000	Weymouth.
Winchendon Electric Light & Power Co.....	Winchendon.....	400	Millers.
		1,060	
		157,727	

MAINE.

Androscoggin Electric Co.....	Deer Rips No. 1.....	6,600	Androscoggin.
	Barker's Mills.....	500	Little Androscoggin.
	Littlefield's No. 2.....	800	Do.
Atlantic Shore Ry.....	Kennebunk.....	3,400	Mousam.
Bangor Railway & Electric Co. (Bangor Power Co.).....	Oldtown, Milford.....	2,000	Penobscot.
Bar Harbor & Union River Power Co.....	Ellsworth.....	9,200	Union.
Bartlett Manufacturing Co., C. H.....	North New Portland.....	3,000	
Belgrade Power Co.....	Belgrade Lakes.....	125	Belgrade Lake outlet.
Berwick & Salmon Falls Electric Co.....	Berwick.....	200	Salmon Falls.
Bridgton Water & Electric Co.....	Limerick.....	2,480	Little Osmipea.
	Bridgton.....	710	Stevens Brook.
	East Brownfield.....	875	
Brownfield Electric Co.....	Calais.....	50	St. Croix.
Calais Street Railway Co.....	Caribou.....	600	Aroostook.
Caribou Water, Light & Power Co.....	Belfast.....	350	
Central Maine Power Co., Penobscot Bay Electric Co.....	Benton.....	200	Sebastocook.
	Bucksport.....	1,200	Orland.
	Foxcroft.....	1,000	Piscataquis.
	Greensville.....	440	Wilson Stream.
	Guilford.....	899	Piscataquis.
	Oakland.....	250	Messalonskee.
	Pittsfield.....	800	Sebastocook.
		1,380	

MAINE—Continued.

Company.	Location.	Rated horse-power.	River.
Bath & Brunswick Light & Power Co.	Brunswick.....	500	Androscooggin.
Central Maine Power Co., Shawmut Manufacturing Co.	Rice River Plant.....	2,500	Sebasticook.
	Shawmut.....	4,000	
	Skowhegan.....	1,420	Kennebec.
	Somerset Traction Plant.....	500	Do.
	Waldoboro.....	128	
	Waterville.....	2,100	Messalonskee.
	Winslow.....	124	Kennebec.
Cherryfield Electric Light Co.....	Cherryfield.....	2,000	Sebasticook.
Clark Power Co.....	Clark's Mills.....	40	Narraguagus.
Cornish & Keser Falls Light & Power Co.	Keser Falls.....	400	Saco.
Cumberland County Power & Light Co.	Hiram.....	380	Ossipee.
	North Gorham.....	3,750	Presumpscot.
	Bonny Eagle.....	1,544	Do.
	West Buxton.....	14,400	Saco.
	Jackman.....	5,380	Do.
Dennistown Power Co.....	Fort Kent.....	150	Moore.
Fort Kent Electric Co.....	Fort Kent.....	125	Wallagras.
Franklin Light & Power Co.....	Farmington.....	800	Carrabassett.
Island Lighting Co.....	Island Falls.....	200	Mattawamkeag.
Kennebunk Municipal Plant.....	Kennebunk.....	100	Mousam.
Lewiston Municipal Plant.....	Lewiston.....	500	Androscooggin.
Lincoln County Power Co.....	Boothbay Harbor.....	650	Damariscotta.
Lisbon Falls Electric Co.....	Lisbon Falls.....	150	
Machias Electric Light Co.....	Machias.....	225	Machias.
Madison Electric Works.....	Norridgewock.....	600	Sandy.
Mallison Power Co.....	South Windham.....	1,000	Presumpscot.
Merrill Mill Co.....	Patten.....	80	Fish Stream.
Milo Electric Light & Power Co.....	Milo.....	500	Sebec.
Monsam Light & Power Co.....	Monsam.....	75	Hebron Pond Outlet.
Municipal Electric Light Plant.....	Bangor.....	600	Penobscot.
Ogunosoc Light & Power Co.....	Rangeley.....	150	Kennebago.
Oxford Electric Co.....	Norway.....	728	Pennigewasset.
	South Paris.....	150	Little Androscooggin.
	Mechanics Falls.....	150	Do.
	Pembroke.....	243	
Pennamquan Power Co.....	Phillips.....	110	Sandy.
Phillips Electric Light & Power Co.....	El. Weir.....	3,000	Presumpscot.
Presumpscot Electric Co.....	Sacarappa.....	2,400	Do.
	Smelt Hill.....	1,000	Do.
	Dundee.....	8,000	
Readfield Light & Power Co.....	Readfield.....	125	Torey Pond Outlet.
Rumford Falls Power Co.....	Rumford Falls.....	28,000	Androscooggin.
St. Croix Gas Light Co.....	Calais.....	450	St. Croix.
Swans Falls Co.....	Fryeburg.....	340	Saco.
Turner Light & Power Co.....	Turner.....	275	Nevinscot.
Weymouth, G. A.....	Farmington Falls.....	150	Sandy.
Yarmouth Lighting Co.....	Yarmouth.....	110	
York County Power Co.....	Sanford.....	120	Mousam.
		123,760	

CONNECTICUT.

Baltic Mills Co.....	Baltic.....	300	Shetucket.
Central Connecticut Power & Light Co.	Leesville.....	200	Salmon.
Connecticut Light & Power Co.....	Bulls Bridge.....	8,000	Housatonic.
Connecticut Power Co.....	Falls Village.....	15,500	Do.
Derby Gas Co.....	Derby.....	1,000	Do.
Farmington River Power Co.....	New Britain.....	1,200	Farmington.
Hartford Electric Light Co.....	Tariffville.....	2,600	Do.
Litchfield Electric Light & Power Co.	Litchfield.....	600	Bantam.
North Connecticut Light & Power Co.	Windsor Locks.....	280	Connecticut.
Rockville-Willimantic Lighting Co...	Thompsonville.....		Willimantic.
Uncas Power Co.....	Willimantic.....	100	Shetucket.
Union Electric Light and Power Co.	Seotland.....	2,000	Farmington.
Wallingford Municipal Plant.....	Unionville.....	300	Quinnipiac.
Winsted Gas Co.....	North Haven.....	175	Mad.
Woodbury Electric Co.....	Winsted.....	320	Pomperaug.
	Woodbury.....	85	
		22,600	

RHODE ISLAND.

Company.	Location.	Rated horse-power.	River.
Blackstone Valley Gas & Electric Co...	Jenks Lane Plant, Pawtucket.	1,125	Blackstone.
Woonsocket, Blackstone Valley Gas & Electric Co.	Woonsocket.....	901	Do.
		2,026	

NEW HAMPSHIRE.

Ashland Municipal.....	Ashland.....	90	Squam Lake.
Bethlehem Electric Light Co.....		450	
Bradford Electric Light Plant.....		77	Warner.
Bristol Electric Light Plant.....	Bristol.....	150	Pemigewasset.
Claremont Power Co.....		600	Sugar.
Colebrook, W. F. Allen Co.....		600	Mohawk.
Concord Electric Co.....		2,000	Merrimack.
Contoosook Electric Light Co.....		250	Contoosook.
Dublin, Keene Gas & Electric Co.....		399	Stanley.
Cloutman Gas & Electric Co.....	Farmington.....	114	Cocheco.
Twin State Gas & Electric Co.....	Gorham.....	1,200	Androscoggin.
Grafton Center, United Mica Co.....	Grafton.....	100	Smith's River.
Greenville Electric Light Co.....		50	Souhegan.
Lyman Falls Power Co.....	Groveton.....	1,336	Upper Ammonoosuc.
Hillsboro Electric Light & Power Co...		300	Contoosook.
Wentworth Hall Electric Co.....	Jackson.....	100	Wildcat Brook.
Keene Gas & Electric Co.....		450	Ashuelot.
Laconia Gas & Electric Co.....		1,950	
Jones & Lincoott, Lancaster Electric Co.		350	Israel.
Grafton County Electric Co., Lebanon Light & Power Co.....		40	Mascoma.
Lincoln, J. E. Henry & Sons Co.....		3,400	Pemigewasset.
Lisbon Light & Power Co.....		600	Ammonoosuc.
Littleton municipal plant.....		800	Do.
Manchester Traction, Light & Power Co.		5,900	Piscataquog.
Milford Light & Power Co.....		250	Merrimack.
Newmarket Electric Co.....		250	Souhegan.
Newport Electric Co.....		300	Exeter.
Peterboro, Keene Gas & Electric Co.....		165	Sugar.
Salem Electric Light & Power Co.....		100	Contoosook.
Tilton Electric Light & Power Co.....	Tilton.....	575	Spicket.
Grafton County Electric Co.....		500	Winnepesaukee.
West Lebanon Light & Power Co.....		550	Mascoma.
W. F. Allen Co., West Stewartson.....	West Stewartson.....	500	Connecticut.
Woodsville Aqueduct Corporation.....		310	Ammonoosuc.
Franklin Light & Power Co.....		1,150	Squam Lake.
New England Power Co., Vernon.....	Vernon.....	32,000	Connecticut.
		57,156	

VERMONT.

Allen Co., W. F.....	Canaan.....	350	
Barton Village.....	Clyde Falls.....	1,000	Clyde.
Bradford Electric Light Co.....	Bradford.....	360	Waits.
Burlington Light & Power Co.....	Colchester.....	3,000	Winooski.
Winooski Valley Power Co.....	Essex Junction Station.....	8,000	
Colonial Power & Light Co.....	Manchester.....	65	Battenkill.
	Cavendish.....	1,500	Black.
Enosburg Falls municipal plant.....	Forest Plant.....	135	Missequoi.
Fall Mountain Electric Co.....	Bellows Falls.....	500	Saxtons.
	North Troy.....	1,300	Connecticut.
		200	Jay Branch.
Hortonville Power Co.....	Gay'sville.....	600	Missequoi.
	Brandon.....	335	White.
	Bethel.....	600	Do.
	Bristol.....	210	Do.
	Salisbury.....	2,200	New Haven.
	Silver Lake.....	3,800	Leicester.
	Hortonville.....	500	Sucker Brook.
Eastern Vermont Public Utilities Co...	Croton No. 1.....	300	Wells.
	Croton No. 2.....	120	Do.
	Barnet.....	365	Stevens Brook.
	South Ryegate.....	350	Wells.
	Joss Pond.....	750	Joss Brook.

VERMONT—Continued.

Company.	Location.	Rated horse-power.	River.
Hardwick municipal plant.....	Hardwick.....	1,600	Lamoille.
Hyde Park municipality.....	.....	250	Gihon.
Island Pond Electric Co.....	West Charleston.....	600	Clyde.
Johnson municipal plant.....	.....	250	.....
Jones & Lamson Power Co.....	Perkinsville.....	400	Black.
Lunenburg Manufacturing Co.....	Lunenburg.....	75	.....
Lyndonville Electric Light Plant.....	Lyndonville.....	900	Passumpsic.
Lyman Falls Power Co.....	Bloomfield plant.....	1,335	Connecticut.
Middlebury Electric Co.....	Middlebury.....	300	Otter Creek.
Missisquoi Power Co.....	Sheldon.....	4,700	Missisquoi.
Village of Morrisville.....	Cady's Falls.....	1,750	Lamoille.
Nelson & Hall Co.....	Famsonville.....	252	Missisquoi.
New England Power Co.....	Readsboro.....	3,800	Greenfield.
Newport Electric Co.....	Newport.....	1,200	Black.
North Troy Electric Light & Power Co.....	.....	200	.....
Pittsford Power Co.....	Pittsford.....	3,600	N. B. E. Creek.
Royalton Power Co.....	Fourth Royalton.....	100	White.
Rutland Railway, Light & Power Co.....	Rutland, Mendon.....	2,700	N. B. E. Creek.
Swanton Village.....	Highgate Falls.....	1,700	Missisquoi.
Sweet-Cummings Co.....	Richford.....	492	Do.
Twin State Gas & Electric Co.....	Bennington.....	258	Roaring Branch.
.....	West Dummerston.....	1,400	West.
.....	St. Johnsbury.....	8,575	Passumpsic.
Vermont Marble Co.....	Perkinsville.....	100	Otter Creek.
Vermont Soapstone Co.....	Stevens Mills.....	600	Missisquoi.
Vermont & Quebec Power Co.....	Richford.....	422	.....
Montpelier & Barre Light & Power Co.; Vermont Power & Lighting Co.	Berlin No. 5 plant.....	850	Winooski.
.....	Middlesex No. 2 plant.....	2,114	Do.
.....	Moretown No. 7 plant.....	451	Mad.
.....	Montpelier No. 4 plant.....	840	Winooski.
.....	Moretown No. 8 plant.....	824	Mad.
.....	North Duxbury No. 1 plant.....	2,800	Winooski.
Public Electric Light Co.....	Fairfax Falls.....	2,700	Lamoille.
Village of Wells River.....	Wells River.....	150	Wells.
Western Vermont Power & Light Co.....	Fair Haven, Carvers Falls.....	2,000	Poultney.
Windsor Electric Light Co.....	Windsor.....	360	.....
Woodbury Granite Co.....	Mackville.....	750	Mackville.
Woodstock Electric Co.....	Woodstock.....	250	Ottawaquechee.
		78,239	

APPENDIX C-14.

ADDITIONAL KILOWATT HOURS POSSIBLE ON EXISTING AND PROPOSED DEVELOPMENTS.

MASSACHUSETTS.

System plant.	Million kilowatt hours.		Added kilowatt capacity at developed sites.	River.
	Present storage.	Proposed storage.		
New England Power Co.:		<i>Davis Bridge.</i>		
No. 6 plant.....	14,000,000	17,000,000	4,000	Deerfield.
No. 1 plant.....	15,000,000	19,000,000	4,500	
Zoar plant.....	20,000,000	40,000,000	10,000	
No. 6 plant.....	15,000,000	21,000,000	5,000	
Davis Bridge storage effect plants 2, 3, 4, 5, 7.....		41,000,000		
East Branch, Westfield River, about Norwich bridge.....		138,000,000	23,500	Westfield.
.....		68,000,000	25,000	
Millers River.....		56,000,000	12,000	Millers.
Nashua River Paper Co.....		9,000,000	2,000	Nashua.
.....		271,000,000	62,500	

MAINE.

System plant.	Million kilowatt hours.		Added kilowatt capacity at developed sites.	River.
	Present storage.	Proposed storage.		
Central Maine Power Co., Bingham.....		88,000,000	26,400	Kennebec.
Shawmut Mfg. Co. (purchased by Central Maine Power Co.).	15,440,000	15,000,000	2,800	
Chace & Harriman:				
Bowhog eddy.....		66,000,000	10,800	
Chase stream.....		108,000,000	18,000	
Steepside.....		156,000,000	24,000	
		483,000,000	82,000	
Rumford Falls Power Co.....	66,189,000	90,000,000	18,000	Androscoggin.
Lewiston, Deer Rips.....	20,563,000	7,000,000	1,800	
		97,000,000	19,800	
Cumberland County Power & Light Co.....	63,174,000	24,000,000	9,000	Saco.
Bangor Railway & Electric Co.....	44,942,000	29,000,000	5,600	
		633,000,000	116,400	Penobscot.

CONNECTICUT.

Connecticut Light & Power Co., Stevenson.....		75,000,000	24,000	Housatonic.
Connecticut River Co., Windsor Locks Development.....		63,000,000	20,000	Connecticut.
		138,000,000	44,000	

NEW HAMPSHIRE.

Hillsboro Electric Light & Power Co.....		30,000,000	10,000	Contoocook.
New England Power Co., Vernon.....		20,000,000	8,500	Connecticut.
Laconia Gas & Electric Co.....		4,000,000	1,000	
Contoocook Falls, Berlin.....		66,000,000	18,000	Androscoggin.
		120,000,000	37,500	

VERMONT.

New England Power Co., Bellows Falls Redevelopment.....		85,000,000	24,000	Connecticut.
Davis Bridge plant.....		71,000,000	21,000	
Weybridge.....		10,000,000	2,700	
Green Mountain at Middlebury.....		10,000,000	2,250	
Vermont Marble Co.....	21,000,000	10,000,000	(1)	
		30,000,000	4,950	
Rutland Railway Light & Power Co.:				East Creek.
Mendon No. 3.....		6,000,000	1,950	
Reconstruction at Mendon.....		1,000,000		
		7,000,000		
East Middlebury.....		10,000,000	4,000	Middlebury.
Hortonia Power Co., Tinmouth.....		8,000,000	2,800	
Montpelier & Barre Light & Power Co.:				Winouski.
Molly's Falls, at Marshfield.....		3,500,000	2,700	
Fallsides between No. 1-2 plants.....		1,500,000	1,800	
		5,000,000	4,200	
		216,000,000	62,600	

1 No additional equipment.

APPENDIX D

Report to the Chief of Engineers, U. S. Army, dealing with
the Electric Power Situation in New Jersey
and Eastern Pennsylvania

Submitted by **MAJ. MALCOLM MACLAREN**, Engineers, U. S. Army
Washington, D. C., February 17, 1919

ELECTRIC POWER IN NEW JERSEY AND EASTERN PENNSYLVANIA.

1. This report treats of the power situation in the territory including Philadelphia and Chester, extending across New Jersey to the Hudson River and taking in the anthracite coal fields of north-eastern Pennsylvania, having special reference to the future development of the electrical systems in each district. A map of this territory is shown on page 78.

RECENT GROWTH OF ELECTRIC POWER COMPANIES.

2. The electric power companies throughout the country are at the present time passing through a transition period. Up to within the last decade they were in general operated primarily as lighting companies, and the supply of power was entirely a secondary consideration, but as the size of such systems has increased, and especially since the development of the steam turbine the cost of central station power has fallen far below the figures obtained from isolated power plants in factories. Certain secondary advantages also may be obtained by the manufacturer by purchasing power, such as the elimination of his own power department, which in general must be quite distinct from the rest of his organization, from the greater flexibility of his power supply, especially in enabling readjustments and extensions to be cheaply made and in obtaining more uniform drive by maintenance of a steady voltage and frequency, all of which tend toward increased production. The result has been that manufacturers have transferred their loads to the public-utility companies in increasing numbers, so that in many cases the growth in the power company's load has far exceeded the rate of industrial development of the district. The effect of the war has been to accelerate this transition on account of the difficulties manufacturers have experienced in obtaining coal and labor.

3. This rapid expansion in the demand for power has made it impossible in most cases for the power companies to provide adequate reserve capacity. It has involved the construction of many large generating plants and the abandonment of smaller stations which would otherwise have been serviceable for many years. Also improvements in design have resulted in the replacement of much apparatus still in good operating condition in order to obtain increased economy. As a consequence of such alterations much capital has become unproductive and most of the power companies of this district at the outbreak of the war were without a normal reserve capacity and with inadequate financial resources for carrying out construction needed to meet the war requirements.

IMPORTANCE OF CENTRAL STATION SUPPLY OF POWER AS A WAR MEASURE.

4. The military advantage of having manufacturers furnished with power from central supply systems has been well illustrated during this war. There has been a huge increase in demand for production from certain industries and a corresponding curtailment of others, and when both classes of industry are supplied from the same power system the reduction in load of one has been utilized to supplement the supply to the other. For example, it became necessary as a war measure to curtail the production of Portland cement in the eastern Pennsylvania district by 25 per cent and power thereby released was used to great advantage by the Bethlehem Steel Co. and others in the manufacture of munitions. Unfortunately only about 30 per cent of the cement companies of the district were connected to the supply system and the power released from cement mills equipped with isolated steam plants could not be utilized for war work. The same conditions were found throughout this territory and numerous attempts were made to utilize the idle capacity of isolated plants, but engineering difficulties, expense, or time required for obtaining relief from such sources generally rendered their use impracticable.

5. Under the pressure of the war's demand for increased production the electric systems of this territory were practically all short of capacity for several months prior to the signing of the armistice, but on the larger systems, where there was a great variety in the character of their output, it had not yet become necessary to curtail the production of the more important war industries as the shortage could be distributed among the factories engaged upon less essential products. If a larger proportion of the factories of these districts had been served with public utility power the flexibility in this respect would have been still greater. The same line of reasoning applies with equal force to the interconnection of adjacent systems, and during the war considerable relief was obtained in certain sections by such means. Construction had been authorized for connecting together the New York Edison and the New Jersey Public Service Electric Cos. systems whereby 20,000 kilowatts additional capacity would have been available in New Jersey, which should have been sufficient to have overcome the immediate power shortage in that district, but this construction was abandoned with the cessation of hostilities when its need as a war measure disappeared. Undoubtedly, however, many such interconnections will be made in the future as the extension of systems brings neighboring circuits into closer proximity.

PRESENT POWER REQUIREMENTS.

6. In order that some sort of a picture may be obtained of the general power situation in this territory an attempt has been made to determine the present total demand for power as contrasted with the amount furnished by the public utility companies. Statistics are available from which fairly satisfactory deductions may be made, though from the nature of the case, great accuracy can not be obtained. Figures have not yet been published covering the

period of the war, but probably in any event it would be desirable to disregard such data as all conditions during that time have been abnormal.

7. This investigation has been limited to the following districts, which, however, cover most of the industrial communities within the territory:

Newark and surrounding territory, limited by Jersey City in the east, Perth Amboy in the south, New Brunswick in the west, and Paterson in the north.

Philadelphia—including the towns on both sides of the Delaware River from Chester to Trenton.

Lehigh district—including the anthracite-coal fields and the territory south to Allentown, Bethlehem, and Easton.

8. The bulk of the power required within these districts may be considered under the following heads:

Lighting.

Industrial power.

Railroads and trolleys.

PRESENT POWER REQUIREMENTS IN THE NEWARK DISTRICT.

9. *Lighting.*—Illumination is at present obtained from electricity, gas, and oil. The municipalities and, in general, the office buildings, hotels, and stores within this district are served from the Public Service Co.'s system. The power required for factory lighting is usually included with the industrial load. It is necessary, therefore, to consider in addition only residences not now connected to the system. The census reports give the population and number of dwellings within this territory for 1910 and estimates of the population for 1917, from which may be derived the approximate number of dwellings in 1917. The records of the Public Service Co. for their lighting customers make it possible to estimate the additional load that would be required if all the dwellings were lighted electrically from the general distribution system. Details of these calculations are given in Appendix D-2, from which it appears that the lighting load at the time of the system peak in 1917 was as follows:

	Kilowatts.
Load from lighting customers.....	25,000
Additional load if all dwellings had been connected.....	12,500
Total.....	37,500
Annual increase from new residences.....	840

10. If allowance is made for the illumination of additional office buildings, hotels, and stores which will come with increasing population, the annual increase in lighting load might reach 1,000 kilowatts. It should be noted in this connection that the effect of the lighting load becomes less important in determining peak conditions as the industrial load becomes predominating, especially since their maximum occurs at different periods in the day.

11. *Industrial power.*—The Census Bureau, in their Abstract of Census of Manufacturers for 1914, give the total primary power required by manufacturers in the various districts under consideration. These figures combine the rated capacity of the engines of isolated plants and the motor capacity of plants using purchased power. Manufacturing statistics are collected by the Census Bureau

every five years and extend back for a considerable period. The records of power-plant capacities, however, have been recorded for only 1909 and 1914. It was thought that the rate of growth indicated by these figures could not be safely assumed as applying for succeeding years without further substantiation, and therefore the records of the value added by manufacturers to the raw materials to obtain the value of the products were also studied as these figures were recorded in the earlier reports. They include cost of power, wages, etc., and should hold a fairly definite relation to the quantity of power required for production. These figures are given in detail in Appendix D-3, and the rate of growth is shown graphically in Appendix D-4. The results are quite consistent among themselves and should give a good indication of the growth for the immediate future. On this basis the total industrial load for the Newark district in 1917 should be 480,000 horsepower, which would correspond to 240,000 kilowatts demand if the entire load had been carried from a single power system. The portion of this load, which was taken by the Public Service Co. in 1917, was approximately 85,000 kilowatts. The annual growth in industrial load for this district as indicated by the above data is 10,000 kilowatts demand.

12. *Railroads and trolleys.*—It is beyond the scope of this report to undertake a detailed investigation of the power required for the operation of the railways in the district, but it is possible to form an estimate of this which should be sufficiently close for our purpose by determining in some detail the power that would be needed for the complete electrification of the New Jersey division of the Pennsylvania Railroad and using these results as a unit of measure which would apply to the other lines. These calculations are given in Appendix D-6, from which it appears that the maximum power required for electric operation under conditions for 1917 would have been about 125,000 kilowatts, or, if the power needed for operations in the immediate vicinity of Philadelphia were added, it would be found that the total requirements for Pennsylvania Railroad lines between New York and Philadelphia and in southern New Jersey would be about 150,000 kilowatts. Seventy-five thousand kilowatts of this could be assigned to the Philadelphia district, 60,000 kilowatts to the Newark district, and the balance to territory outside these areas.

13. A study of the railroad map for the Newark district indicates that the Pennsylvania Railroad lines constitute about 30 per cent of the total when reduced to a single-track basis. Assuming equal traffic per mile of track, the total power required for railroads would be 200,000 kilowatts. As the traffic on the Pennsylvania lines is probably heavier than the average of the others, this should represent an outside limit. All of the trolley lines of the district are operated by the Public Service Co. and required a maximum of about 75,000 kilowatts in 1917.

14. Summarizing the above, the total load for the Newark district for 1917 would be—

	Kilowatts.
For lighting	37,000
For industrial power	240,000
For railroads and trolleys	275,000
Total	552,000

The Public Service Co. carried 155,000 kilowatts of this load.

PRESENT POWER REQUIREMENTS IN THE PHILADELPHIA DISTRICT.

15. *Lighting*.—Following the same procedure as for the Newark district, it is found that the lighting load should be as follows:

	Kilowatts.
Electric companies' commercial lighting load.....	35,000
Electric companies' municipal lighting load.....	10,000
From residences not served by the electric companies.....	35,000
From office buildings, etc., not served by the electric companies.....	15,000
Total	95,000

16. The annual increase in demand from new residences should be 800 kilowatts, or allowing for growth of office buildings, etc., this might reach 1,200 kilowatts. For details from which these figures are derived see Appendix D-2.

17. *Industrial power*.—The figures given in Appendix D-4 indicate that the total industrial load for this district for 1917 should be 630,000 horsepower, or 320,000 kilowatts maximum demand on a central system, of which the public utility companies are carrying approximately 100,000 kilowatts maximum demand. The annual growth in load in this district is approximately 12,000 kilowatts.

18. *Railroads and trolleys*.—As indicated above the Pennsylvania Railroad lines in the Philadelphia district should require approximately 75,000 kilowatts. An inspection of the railroad map and passenger time-tables show that these lines constitute about 50 per cent of the total, so that the total railroad load should be about 150,000 kilowatts. The load from trolleys and electric railroads is about 120,000 kilowatts.

19. The total load for the Philadelphia district would be:

	Kilowatts.
For lighting.....	95,000
For industrial power.....	320,000
For railroads and trolleys.....	270,000
Total	685,000

The public utility companies carried 250,000 kilowatts of this load.

PRESENT POWER REQUIREMENTS IN THE LEHIGH DISTRICT.

20. *Lighting*.—Aside from the lighting used in industry and included in the industrial load, the requirements for illumination in this district are very small and do not occur at the time of maximum demand on the electrical systems and can, therefore, be neglected.

21. *Industrial load*.—By far the largest part of the power in this district is used in mining and transporting coal. There is probably no place in the country where there is a more wasteful use of fuel than in this region. A large part of the demand is for pumping where inefficient steam pumps are used, which in many cases are supplied with steam through pipe lines a mile or more in length. The reason such operation has been tolerated is that the finer sizes of coal have been used in the boilers and have been considered until recently a waste product. Methods of burning this coal efficiently on a large scale have now been developed, and improvements are

being devised which should create a steady commercial demand for this low-grade coal. Stimulated by this demand, a sufficient number of collieries already have been electrified to demonstrate that great economies can be effected thereby, and it is believed that the process of conversion to electric operation will continue at a rapid rate. It is shown in Appendix D-6 that if all the mines are electrified and operated from a general supply system the maximum demand should be approximately 380,000 kilowatts and the saving in coal, after making liberal allowance for electric operation, should exceed 6,000,000 tons annually.

22. The annual production of cement in this district averages about 24,000,000 barrels, or 80,000 barrels on a maximum day. This calls for a very steady 24-hour demand, which tests show will average close to 0.75 kilowatt per barrel per day, or 60,000 kilowatts. At present about 25 per cent of this load is carried by public supply companies.

23. The largest consumer of power in the district is the Bethlehem Steel Co. This supplies most of its own power needs from the waste products of its blast furnaces. It also takes a maximum demand from the Lehigh Navigation Electric Co. of 10,000 kilowatts.

24. Other miscellaneous industrial demands, as shown in Appendix D-7, amount to about 62,000 kilowatts maximum demand, approximately one-half of which is carried by the power companies. This appendix also gives the annual production of coal and cement for the district since 1900.

25. *Railroads and trolleys*.—Assuming that 80,000,000 tons of coal would be hauled annually for an average distance of 50 miles before leaving the Lehigh district, the same method of calculation as given in Appendix D-5 shows that approximately 80,000 kilowatts maximum demand would be required if all of the steam roads in the district were electrically operated. About 20,000 kilowatts additional would be required for the movement of passengers and miscellaneous freight, making the total 100,000 kilowatts. The records of the power companies in the southern half of the district show that the maximum power taken by the trolleys is 15,000 kilowatts. About an equal demand is required for those in the balance of the territory, giving a total of 30,000 kilowatts.

26. Summarizing the above, it appears that the total demand for power in the Lehigh district is as follows:

	Kilowatts.
For coal mines.....	380,000
For cement production.....	60,000
For miscellaneous industries.....	72,000
For railways and trolleys.....	130,000
Total.....	642,000

The public-utility companies carried 125,000 kilowatts of this load.

FUTURE DEMAND FOR ELECTRIC POWER.

27. The rate at which industrial and railway loads may be converted to electric operation from central station supply systems must be necessarily a matter of considerable uncertainty; and, furthermore, no proper allowance can be made for the use of new appliances,

such as electric furnaces and heaters, in industry, the electrical welding of ship plates, etc., and all estimates may be materially altered if Philadelphia and Newark become great shipping ports. It seems futile, therefore, to attempt to speculate upon how much power these unknown requirements would involve. In the light of the above discussion, however, it would appear that within the next decade the power companies should provide capacity in excess of the present total power demands in these districts, namely:

	Kilowatts.
In the Newark district.....	552,000
In the Philadelphia district.....	685,000
In the Lehigh district.....	642,000

28. The present capacity of the power systems available for supplying these demands, including additions under construction or for which plans are fully developed, are given below, together with the additional capacity that would be required to meet future needs.

	Capacity completed or projected.	Additional capacity needed within 10 years.
	Kilowatts.	Kilowatts.
Newark district.....	300,000	280,000
Philadelphia district.....	500,000	200,000
Lehigh district.....	200,000	450,000

SUGGESTED METHOD OF PROVIDING ADDITIONAL CAPACITY.

29. In order that every incentive should be offered to industries and to the railroads to conserve fuel and labor by obtaining their power from the most efficient source, it is important that the public-utility companies should exercise the greatest economies in the production of their power and that they should provide adequate reserve both in generator capacity and in distribution circuits so as to insure reliability of service. In addition to the local construction contemplated by the various companies, the following methods are suggested for producing these results:

By interconnection of systems.

By construction of steam plants at the mines,

By hydroelectric developments on the Delaware River.

By hydroelectric developments on the Susquehanna River.

30. *Interconnection of systems.*—There has been a growing tendency within recent years for neighboring companies to interconnect their systems, which has resulted in reducing the peak load, in a more comprehensive use of the available reserve, and in improving voltage conditions. Within the territory under consideration a number of such projects are contemplated. It is proposed to run a high-tension line from the Lehigh Navigation Electric Co.'s, circuits at Hazleton through Wilkes-Barre to Scranton, a distance of 45 miles. Another line is projected and the right of way has been purchased for most of the distance which will connect Easton and Reading and tie into the Lehigh Navigation Electric Co.'s, system, as shown on the map on page 78. The northern and southern zones of the Public Service Electric Co. are to be tied together by a line between New Brunswick and Trenton.

31. A much more extensive project is being investigated for connecting the Philadelphia and New Jersey systems together and each of these to the Lehigh Navigation Electric Co.'s system. A study of the peak loads on these three systems during the winter of 1917-18 shows that the combined peak, if such interconnection had existed, might have been 20,000 kilowatts less than the sum of the individual peaks, which would have resulted in a direct saving in this amount of capacity. This difference should increase as the systems grow, and when taken in connection with the saving in reserve required with interconnection the total might ultimately reach 100,000 kilowatts.

32. As noted above, an interconnection between the New Jersey and New York circuits was being made as a war measure. It is difficult, however, to obtain full benefit from such an arrangement during normal times, as the principal circuits on the New Jersey side operate at 60 cycles while the frequencies in New York are 25 and 62½ cycles.

33. *Steam plants at the mines.*—There are obvious advantages from an economic point of view in generating power at the mines and delivering it to the market by means of transmission lines in preference to hauling the coal to the market over the congested railways, which consume more coal before it is transformed into electrical energy. In order, however, that this question should be thoroughly understood in connection with the generation of power in the anthracite field of eastern Pennsylvania, there are a number of points that should be considered. In the first place there is the question of the grade of coal that can be successfully used. It has been found that with specially designed grates and with Coxe stokers it is possible to use No. 3 buckwheat and smaller sizes, 30 per cent of which will pass through a one-thirty-second-inch screen. Under these conditions about 5 pounds of steam may be evaporated per pound of coal. This is about as poor a grade of coal as can be considered practical at the present time, though improvements continue to be made tending toward the use of smaller sizes. Very promising investigations are being made upon the use of powdered coal for fuel, but these can not yet be considered as having passed the experimental stage.

34. There is next the question of the quantity of this coal that is being produced. The percentage of the smaller sizes varies in the different districts, being highest and of the best quality in the southwestern part of the field. Figures showing the relative sizes, as given below, were obtained from one of the large operators having mines in each district and should, therefore, be representative of the average:

	Per cent.
Broken.....	8.3
Egg.....	10.6
Stove.....	14.7
Nut.....	22.8
Pea.....	9.4
No. 1 buckwheat.....	16.9
No. 2 buckwheat.....	9.3
No. 3 buckwheat.....	6.9
No. 4 buckwheat.....	1.6
	<hr/> 100.0

35. These only cover the product that was sold. No record was kept on the refuse nor of the quantities of each size used for power at the mines, although it is known that no coal was used for power larger than No. 2 buckwheat, and most of it was smaller than this. From these and other data it would seem that about 20 per cent of the total production may be taken as the amount of No. 3 and smaller sizes suitable for power purposes that will be produced on the average. This means that the annual production of such coal in the anthracite region would amount to about 16,000,000 tons. More than one-half of this is now being used at the mines for power, but with electric operation there should be at least 14,000,000 tons available for other purposes.

36. Closely associated with this question of available supply is that of the relative value of the product. If it was on an equality with bituminous for power purposes, it could undoubtedly command an equal price, with such differential as might be necessary for freight, but as the analysis of this grade of anthracite will show about 11,000 B. t. u. and over 18 per cent ash, while the bituminous used in the East for power purposes should give 14,000 B. t. u. and about 9 per cent ash, it is evident that it is not sufficient to place them upon an equal heat basis, but the anthracite price must be further discounted because of the fact that the power plant designed for burning bituminous would require 25 per cent less boilers and coal-handling equipment and 50 per cent less ash-disposal apparatus. The anthracite also requires rather more careful watching, especially with fluctuating loads, on account of its being low in volatiles. For this reason it has been proposed to use a mixture of anthracite and bituminous, although this has not been done to any great extent. The price which may be obtained for this coal is of course largely controlled by the demands of the market and it is interesting to note in this connection that 10 years ago a mixture of No. 2 buckwheat and smaller sizes could be purchased for 25 cents per ton at the mines, and that as methods were developed for the economical use of such fuel the price increased until it was quoted as high as \$2.60 per ton during the war. At present the problem of disposing of this coal is causing the operators a good deal of concern. This may retard the electrification of these mines as the principal object of this is to release more of this low-grade fuel. On the other hand, the conditions should be favorable for a power company desiring to construct a large plant in the coal fields to obtain coal at a sufficiently favorable price on the basis of a long-term contract to justify such a development.

37. The selection of a proper site for a plant of 150,000-kilowatt capacity, which is an economical size to consider in this connection, should be governed largely by the adequacy of the coal and water supply. Such a plant would require about 2½ pounds of this low-grade fuel per kilowatt hour, and if operated at 60 per cent load factor would consume 850,000 tons annually, or if the load factor could be increased to 70 per cent, the annual consumption would reach 1,000,000 tons. As shown in Appendix D-6, there is no single group of mines having an output of this amount, assuming 20 per cent of its total production could be utilized. In some localities the culm banks would reinforce the supply, but these have now been so thor-

oughly worked over that their presence could not materially affect the choice of site for a plant of the size contemplated. Local transportation would therefore, be required for part of the fuel. The freight rates that have been filed with the Interstate Commerce Commission by the coal-carrying roads show that the rates on coal within a 10-mile radius average \$1 per ton. Under favorable conditions, this might be reduced either by the public carriers or by the construction of private lines. In any event, however, it is an important matter to consider in connection with the coal supply.

38. The water conditions in this territory impose further restrictions upon the selection of a site. It is necessary not only that there should be an abundant supply of cool water for the condensers, but also that the boiler feed should be uncontaminated by the mine water which contains sulphur and is unsuitable for the purpose. In the ultimate development of a comprehensive power system for this territory, the most satisfactory arrangement would probably be to locate one large plant in the Wilkes-Barre district, one on the Susquehanna River near Lykens, and a third on the headwaters of the Schuylkill, although it may be found that limitations in water supply and the high cost of local transportation for coal will lead to the construction of a larger number of plants of smaller individual capacity, which will be more widely distributed throughout the district and connected together by transmission lines.

39. When it comes to the question of the supply of power from the coal fields to the Newark and Philadelphia districts, it should be noted that aside from the matter of transportation there are many advantages in building the plant near the city, especially in the fact that coal may be drawn from a much wider territory without additional freight charges and also bituminous coal would be available in an emergency. The water conditions are also more favorable, as well as the market for labor and supplies. It must also be recognized that the reliability of service is greater from a modern generating plant located near the consumer than at the end of a long-distance transmission line. It is difficult to evaluate such matters, but it is possible to obtain a direct comparison between the net cost of freight charges for the long haul on the coal in one case and the cost of the energy loss and fixed charges on the transmission lines required in the other. This has been done in Appendix D-8. The transmission-line costs are based upon copper at 17 cents and steel at 6 cents. The allowance that has been made for freight charges in the case of the long haul has been determined by deducting from the total the cost of local transportation required for a plant located at the coal fields. This is subject to some uncertainty, as it depends upon the location of the local plants with reference to the coal supply, but, as indicated above, the charge for local freight is \$1 per ton and the charge from the center of the district to either Philadelphia or Newark is \$1.80 per ton, with the possibility of a reduction after the reconstruction period. Remembering that it will not be necessary to haul the entire supply to the plant at the mines, a difference of \$1 per ton as used in the estimate should be conservative. On this basis it is seen that for load factors less than 75 per cent it would be more advantageous to build the plant near the market than at the mines, but if such transmission lines could be

kept well loaded up to their capacity for 24 hours a day and at the same time they could be utilized to obtain the benefits of interconnection referred to above, their construction would be fully justified.

40. The following conclusions may be drawn from the above discussion, that as a fuel conservation measure it would prove of the greatest value to electrify the mines in this region, saving thereby over 6,000,000 tons of coal annually; in order that this should be accomplished, it would be necessary to find a market for the coal released. This could be accomplished by building large generating plants in the coal fields to serve the mines and at the same time demonstrate on a large scale that this low-grade anthracite is suitable for general power purposes. With the construction of such plants, interconnecting transmission lines should be built to Philadelphia and Newark, which would be utilized for transmitting a large quantity of power from the coal fields at slightly less cost than it could be produced locally and with considerable saving in rail transportation.

HYDROELECTRIC DEVELOPMENTS ON THE DELAWARE RIVER.

41. The Delaware River has not proved favorable up to the present for the development of hydroelectric installations on account of having an extremely low-water period during the summer. However, consideration has been given to the control of the flow by means of reservoirs at the headwaters of the river and its tributaries whereby a large amount of power could be obtained throughout the driest seasons.

42. A comprehensive study of the power possibilities of the Delaware on this basis was made by Dr. Louis Duncan and Henry A. Pressey, and later thoroughly checked and substantially confirmed by George A. Orrok of the New York Edison Co. (report of February, 1913). The general plan is to utilize the fall of the Delaware for about 125 miles of its length, from Hancock, N. Y., to below Belvidere, N. J. Within this distance there is a fall of 675 feet, of which 527 feet will be utilized by the construction of 10 power plants, giving a minimum output of 300,000 horsepower for 12 hours a day, or approximately 990,000,000 kilowatt hours for a year of minimum flow. The location of the proposed reservoirs and power plants are shown on the map on page 78. Six reservoirs are to be provided, having 40,000,000,000 cubic feet capacity. These will govern the river flow so as to make it practically uniform throughout the year and eliminate flood conditions. The total drainage area of the river to Belvidere is 4,376 square miles, of which—

2, 405 square miles are in the State of New York.

329 square miles are in the State of New Jersey.

1, 647 square miles are in the State of Pennsylvania.

43. Records of rainfall and run-off have been kept at a sufficient number of points to give a fairly accurate history of the water conditions of the river for the last 50 years. These show that the minimum flow occurred during 1910 and the minimum annual production of 990,000,000 kilowatt hours is based upon conditions for that year. During an average year considerable secondary power could be produced in addition to the above. The following data have been taken

from Mr. Orrok's report regarding the reservoirs necessary to control the flow and give the desired output during the driest seasons:

Reservoir.	Drainage area.	Capacity.	Height of dam.	Cost of construction exclusive of land.
	<i>Sq. miles.</i>	<i>Cubic feet.</i>	<i>Feet.</i>	
Cannonsville	480	12,000,000,000	150	\$780,000
Cadosia	900	5,000,000,000	100	571,000
East Branch	520	7,000,000,000	120	340,000
Colchester	450	8,000,000,000	100	375,000
Livingston Manor	73	3,000,000,000	.....	182,000
Shohola	61	5,000,000,000	100	100,000
Total .....	.....	40,000,000,000	.....	2,348,000

44. The New York State Water Supply Commission have studied the Cannonsville site and have proposed the construction of a 120-foot dam at this point purely for the sake of the water control. All the other dam sites both for the reservoirs and power plants have been investigated by competent engineers who report that no unusual structural difficulties should be encountered.

45. The banks along most of the length of the river covered by these developments are high above the natural water surface so that the amount of land flooded by the construction of the power dams would be small. The railroads are in general well above the level of the proposed dams except along the East Branch, where it would be necessary to elevate the single track line of the Delaware & Eastern Railroad for about 15 miles.

46. The reservoirs are designed to provide a minimum flow of 2,670 second-feet at Hancock, which will be increased by the natural flow of the unstored tributaries and by the reservoirs below Hancock and above the various power sites in such a way that the power indicated in the following table may be developed for 12 hours per day throughout the year. These figures assume an over-all efficiency of 66 per cent.

No. of station.	Normal rating of station.	Normal rating of apparatus installed.	Fall.	Height of dam.	Length of canal.	Drainage area.
	<i>H. P.</i>	<i>H. P.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Miles.</i>	<i>Acres.</i>
1	21,000	24,000	40	20	2½	1,648
2	32,000	36,000	35	60	5½	1,925
3	60,000	70,000	100	75	3	2,779
4	38,000	60,000	85	47	2½	2,844
5	28,500	40,000	500	100	5	190
6	28,000	32,000	40	40	0	3,474
7	21,000	24,000	30	20	2	3,328
8	30,000	32,000	42	29	2½	3,780
9	30,000	24,000	28	10	5	3,520
10	51,000	60,000	67	45	2½	4,378
Total horsepower	344,500	426,000				
Total kilowatts	270,000	318,000				

47. The estimated cost of this complete development based upon prewar conditions is \$31,500,000 as shown in Appendix D-9. This is approximately \$100 per kilowatt of installed capacity, or \$140 per

kilowatt delivered after making liberal allowances for reserves and transmission losses. These estimates have not been checked and undoubtedly would not hold under present conditions, but it does not seem necessary to bring them up to date as it is proposed to construct at present only two reservoirs, those at Cannonsville and Shohola and power houses No. 2 and No. 4. This construction should furnish 120,000 horsepower of installed capacity or 75,000 kilowatts delivered for 4,000 hours during a dry year. A recent estimate for the cost of this part of the work and including land and rights for the complete development is \$12,000,000. The estimated returns upon this investment appear ample to attract private capital to the enterprise as soon as Congress acts upon the water power bill now pending or releases its hold upon power developments upon navigable streams which has been enforced during the discussion of the bill.

PAUPACK DEVELOPMENT.

48. Closely associated with these Delaware developments, but under the control of different interests, is the Paupack project. In this case, by the construction of a 50-foot dam, it is possible to obtain a reservoir of 8,500,000,000 cubic feet capacity for a drainage area of 238 square miles. From records furnished by L. B. Stillwell it appears that for a year of average rainfall it should be possible to utilize the entire run-off and develop 80,000,000 kilowatt hours on the basis of the maximum head, or about 70,000,000 kilowatts with the average available head. Allowing for transmission losses, this would equal about 65,000,000 kilowatt hours delivered. The site for the power plant is 25 miles from Scranton and a connection could readily be made with the proposed transmission line between Scranton and Hazleton, thus making this power available for the whole district.

49. A study of load curves of the power companies serving this territory show that there are no great seasonal changes in the load and that the peaks may occur at any time during the eight-hour working day. As the loads are light on Sundays and holidays, Paupack should be developed to carry as much load as possible for eight hours per day, 300 days per year. This would correspond to approximately 27,000-kilowatt average load. In order that Paupack should be capable of taking such peaks as might occur above this average, the plant should be designed for 40,000-kilowatt capacity.

50. Without attempting great refinement in estimating the cost of this development, it appears from figures prepared by private engineers in 1916, as shown in Appendix D-10, that the total cost of a 40,000-kilowatt plant, including transmission line to Scranton but exclusive of cost of property, would be approximately \$79.50 per kilowatt, and that the cost of energy delivered, including fixed charges and transmission losses, would be 5.8 mills per kilowatt hour. This is certainly a low figure for the cost of power, remembering that it is purely a peak load at a load factor of about 20 per cent.

51. The Paupack project might be justified under the conditions named above upon its own merits, but when taken in connection with the Delaware developments, it becomes still more valuable, for the discharge from the Paupack reservoir would contribute materially

to the capacity of all but three of the plants proposed for the Delaware. In the ultimate development, all of these hydroelectric plants should be operated as a single system and be interconnected with large capacity transmission lines to the coal fields and the Philadelphia and Newark districts. They should carry the day loads to the maximum of their capacity. The same transmission circuits should be utilized to carry off peak power from the coal fields to the cities. The hydroelectric plants would thus be operated under their most favorable conditions; the steam plants at the coal fields, where the conditions are favorable for producing cheap power, would be operated at high load factor; the load factor of the transmission lines would also be high, thus minimizing the cost of capital charges upon the transmitted power and the minimum amount of coal would be burned at the cities.

52. It has been assumed above that all of this transmitted power would be absorbed in the Newark and Philadelphia districts, but with comparatively little additional complication, due to differences in frequency, power might also be delivered to New York.

53. There are further possibilities of obtaining additional power from the Neversink, Shohola, and other tributaries of the Delaware, but these may be considered as future developments of the general scheme outlined above.

HYDROELECTRIC DEVELOPMENTS ON THE SUSQUEHANNA RIVER.

54. In order that the capacities indicated above as needed for these districts should be provided without having a preponderance of steam plants, it would be desirable to develop additional hydroelectric power on the Susquehanna. Plants are already in successful operation on this river at York Haven and Holtwood, the former serving Harrisburg and York, and the latter Baltimore and Lancaster. It is proposed to construct a larger plant than either of these at Conowingo, near the mouth of the river. For location see map, page 78. This project has been studied by a number of engineers during the past 15 years so that the general features are well understood. The stream-flow data as determined by the United States Geological Survey covers a period of 25 years. The records of the operation of the plant at Holtwood also furnish valuable information regarding the power possibilities at this site.

55. The river flow varies from a minimum of 3,000 second feet to 600,000 second feet with an average during a normal year of about 50,000 second feet. The Holtwood plant operates under a head of 45 feet minimum and 65 feet maximum. With a rated capacity of 82,000 kilowatts, the plant has carried peaks of 86,000 kilowatts. Twenty-one thousand second feet are required for full capacity, so that only about 15 per cent of this capacity can be obtained during the driest periods. Much the same conditions will prevail at Conowingo where it is proposed to develop a somewhat higher head and install about 120,000 kilowatts generating capacity. The records at Holtwood for 1917, which is the first year in which there has been a market for their power at all times, show that the capacity is restricted for a comparatively small part of the year, as the yearly load factor was 70 per cent. The total production for 1917 was

517,000,000 kilowatt hours, and it is estimated that for Conowingo for like river conditions the output should be 700,000,000.

56. The dam at Conowingo would back up the water to the tail-race at Holtwood. The river banks are fairly steep for most of the distance, so that comparatively little land would be flooded. The most serious difficulty to be encountered would be the relocation of the railroad, which follows the eastern bank of the river, and the best method of providing for this apparently requires further investigation. Estimates prepared by private engineers for the cost of the development are given in Appendix D-11. These indicate that on the basis of prices prevailing in 1917, the total cost, including transmission to Philadelphia, would be \$17,233,000, or \$143 per kilowatt of installed capacity. On the basis of an annual production of 700,000,000 kilowatt hours, or 630,000,000 kilowatt hours delivered, it should be possible to deliver this power in Philadelphia at a cost of approximately 3 mills per kilowatt hour. This is river flow power, varying in amount with the seasons and river stages.

57. With the Conowingo development it would be possible to arrange for an interchange of power between Philadelphia and Baltimore. This could not be done by direct interconnection of circuits on account of the difference in frequency, but by placing 60-cycle generators at Holtwood in addition to the present 25-cycle machines, and installing both 25-cycle and 60-cycle units in Conowingo and interconnecting the two plants, considerable flexibility could be provided for shifting load between the two districts.

58. In order that the hydroelectric developments on the Susquehanna should be utilized to better advantage than is possible at present, it is desirable that storage reservoirs such as suggested for the Delaware should be constructed, which would regulate the river flow and provide the requisite amount of water to obtain full capacity during dry periods. These reservoirs could also be arranged so as to provide additional power locally, which could be utilized to advantage in the district.

CONCLUSIONS.

59. In order to provide for the rapidly increasing needs in the Newark, Philadelphia, and Lehigh districts for electric power both for industrial uses and for the electrification of railroads, there should be provided during the next 10 years approximately 900,000 kilowatts in generating capacity, in addition to the new construction already undertaken or for which plans have been developed by the public utility companies serving these communities. Under the plans recommended in this report, this capacity would be made up of hydroelectric power from the Delaware and Susquehanna Rivers and steam plants at the anthracite mines, all of these reinforcing the steam plants constructed near the local power markets which in general burn bituminous coal. These plants would be well distributed over the territory and thoroughly interconnected by a comprehensive distribution system in such a way as to efficiently utilize the capacity of the distribution circuits with the minimum expenditure for transmission lines. This should not only provide cheap and reliable power throughout the entire territory under normal conditions, but should

give the maximum flexibility to meet emergencies, for the power would be derived in approximately equal amounts from bituminous coal, anthracite coal, and water, and with the proposed transmission system, the reserve capacity of the entire network could be utilized for any district and large quantities of power could be delivered at any congested point without the use of rail transportation. Such a system should greatly assist in the industrial development of the community and by stimulating manufacturers and mine operators to abandon their inefficient isolated steam plants should result in a large conservation of fuel and labor.

MALCOLM MACLAREN,
Major, Engineers, United States Army.

LIST OF APPENDIXES TO APPENDIX D.

APPENDIX 1. Map of the district opposite page 78.

2. Estimate of residential lighting load.
3. Industrial statistics for Newark and Philadelphia districts.
4. Growth in industrial load Newark and Philadelphia districts.
5. Estimate of power required for railroads.
6. Estimate of power required for coal mines.
7. Industrial statistics for Lehigh district.
8. Comparison of cost of electrical transmission and coal transportation.
9. Cost of hydroelectric developments on Delaware River.
10. Cost of hydroelectric development at Paupack.
11. Cost of hydroelectric development at Conowingo.

APPENDIX D-2.

ESTIMATE OF RESIDENTIAL LIGHTING LOAD.

Population in New Jersey—Newark district.

CITIES ABOVE 25,000.¹

	1910, from census.	1917 Cen- sus Bureau estimate.	Number of dwellings in 1910.
Bayonne.....	55,545	72,204	6,147
East Orange.....	34,371	43,761	6,108
Elizabeth.....	73,409	88,830	10,060
Hoboken.....	70,324	78,324	4,433
Jersey City.....	267,779	312,557	27,805
Newark.....	347,469	418,789	38,668
Orange.....	20,630	33,636	4,391
Pasaden.....	54,773	74,478	5,135
Paterson.....	125,600	140,512	15,812
Perth Amboy.....	32,121	42,646	4,209
West Hoboken.....	35,403	44,398	5,723
	1,126,414	1,350,113	126,546

CITIES 10,000 TO 25,000.¹

Bloomfield.....	15,070	19,013	2,661
Garfield.....	10,213	15,109	1,376
Hackensack.....	14,050	17,412	2,685
Harrison.....	14,498	17,345	1,659
Irvington.....	11,877	16,710	1,991
Kearney.....	18,689	24,325	2,676
Montclair.....	21,550	27,087	3,479
New Brunswick.....	23,388	25,855	3,368
Plainfield.....	20,550	24,330	3,928
Union.....	21,023	25,370	2,425
West New York.....	13,560	19,613	1,643
West Orange.....	10,980	13,964	1,517
	196,418	246,123	30,206

¹ 20.1 per cent increase in 7 years, 2.87 per cent per year; 3,579 dwellings increase per year.

² 26 per cent increase in 7 years, 3.71 per cent per year; 1,170 dwellings increase per year.

CITIES 2,500 TO 10,000.³

12 towns.....	53,190	(⁴)	9,615
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³ Allow 4 per cent per year, giving 384 new residences per year.

⁴ No record.

Population in New Jersey—Newark district—Continued.

TOTALS.

	1910, from census.	1917, Census Bureau estimate.	Number of dwellings in 1910.	New residences per year.
Cities above 25,000.....	1,126,414	1,350,113	126,546	3,579
Cities 10,000 to 25,000.....	196,418	246,123	30,208	1,179
Cities 2,500 to 10,000.....	83,190	86,317	9,616	384
	1,375,022	1,651,553	166,369	5,133

$5,133 \times 7 = 35,931$ dwellings increase in 7 years, or 202,300 total in 1917.

Population in Philadelphia district.¹

	1910, from census.	1917, Census Bureau estimate.	Number of dwellings in 1910.
Chester.....	38,537	41,857	7,769
Philadelphia.....	1,546,006	1,736,514	296,220
Bristol.....	9,256	10,826	1,745
Camden.....	94,538	108,117	20,260
Trenton.....	96,815	113,974	17,932
Gloucester.....	9,462	11,375	2,068
Burlington.....	8,336	9,024	1,864
	1,805,952	2,080,687	346,848

¹ 12 per cent increase in 7 years, 1.86 per cent per year; 6,450 dwellings increase per year.

346,848 dwellings in 1910 increased by 12 per cent gives 387,000 dwellings for 1917.

ESTIMATE OF LIGHTING LOAD—NEWARK DISTRICT.

Annual Report of Public Service Corporation for 1917 shows meter connections, total number.....	159,131
Deduct for power customers.....	8,000
	156,131
Deduct for lighting customers—southern zone.....	20,000
Total lighting customers—Newark district.....	136,131
Power used for commercial lighting during November, 1917, in Newark district was (kilowatt hours).....	8,279,000
This gives an average load of (kilowatts).....	11,500
On this basis the lighting load at the time of the system peak should be about (kilowatts).....	25,000

Average load for lighting customer 25,000,000 watts ÷ 136,131 equals 183 watts.

As meter connections to apartments, offices, stores, etc., are included in the above, it is probable that the strictly residential connections in the Newark district total about 100,000.

The census report shows approximately 200,000 residences for the district, which leaves 100,000 not connected. The load from these at 5 p. m., the time of the peak, should average about 125 watts, which gives a total demand of 12,500 kilowatts.

The annual increase in demand from new residences should be $5,133 \times 0.125 = 640$ kilowatts.

ESTIMATE OF LIGHTING LOAD—PHILADELPHIA DISTRICT.

The number of residential customers is approximately 110,000, leaving about 202,000 not connected, which at 125 watts would require 35,000 kilowatts.

The annual increase in demand from new residences should be $6,450 \times 0.125 = 800$ kilowatts.

APPENDIX D-3.

INDUSTRIAL STATISTICS.

[From Census Bureau Abstract for 1914.]

NEWARK DISTRICT.

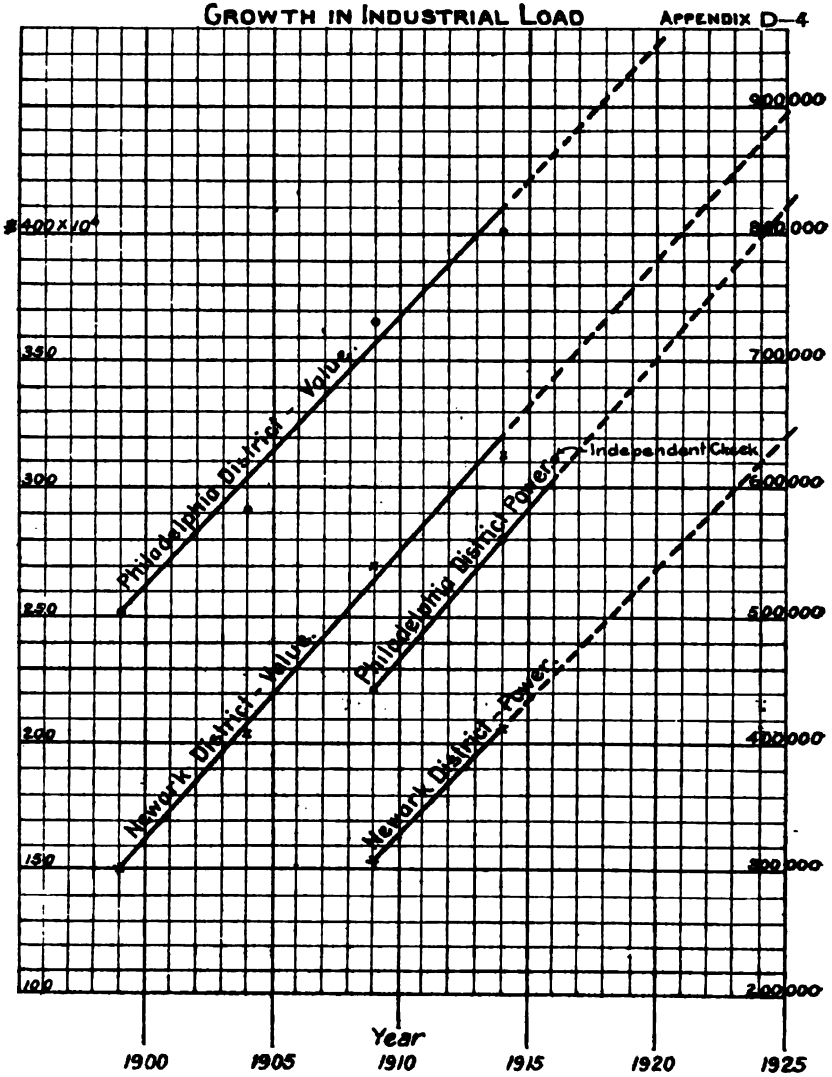
	Primary horse-power.		Value added by manufacturers expressed in thousands.			
	1914	1909	1914	1909	1904	1899
Bayonne.....	33,323	28,094	\$20,525	\$14,709	\$13,650	\$4,807
Bloomfield.....	8,353	6,081	4,998	3,694	2,740	2,030
East Orange.....	3,379	1,087	3,018	1,957	1,219	1,176
Elizabeth.....	25,520	20,124	14,921	12,718	12,320	9,948
Garfield.....	8,574	5,416	4,748	2,919	1,790	1,100
Hackensack.....	1,343	1,021	1,201	1,079	830	620
Harrison.....	15,981	8,381	10,603	8,129	4,780	2,885
Hoboken.....	14,429	10,612	12,785	10,650	7,497	5,457
Jersey City.....	49,086	35,917	52,746	39,458	26,942	22,664
Kearny.....	10,409	7,235	6,665	4,409	923	623
Montclair.....	1,132	918	439	357	202	278
New Brunswick.....	9,619	6,337	8,247	5,456	4,759	2,797
Newark.....	100,466	78,203	97,163	87,261	89,366	51,966
Orange.....	2,906	2,812	2,619	2,017	1,540	1,140
Parsippany.....	31,701	23,985	22,328	16,970	9,673	5,387
Paterson.....	34,017	34,989	37,799	34,527	27,232	23,447
Perth Amboy.....	48,968	29,787	13,215	14,521	11,000	7,500
Plainfield.....	4,064	3,912	2,248	2,119	2,418	1,628
Union.....	2,908	1,829	2,375	3,405	2,120	1,965
West Hoboken.....	2,299	1,477	3,771	3,089	2,825	2,340
West New York.....	2,455	1,443	3,916	1,865	1,430	1,060
Total.....	410,972	308,721	326,380	270,609	205,356	150,734

PHILADELPHIA DISTRICT.

Chester.....	19,160	17,131	\$7,920	\$7,797	\$3,223	\$3,369
Philadelphia.....	465,678	365,708	333,308	315,670	258,036	224,907
Camden.....	39,670	29,056	35,730	21,754	13,164	7,528
Trenton.....	36,219	29,839	24,879	21,442	14,809	11,877
Total.....	560,727	441,734	400,832	366,663	292,232	250,571

1 No records; figures estimated from average for district.

The loads carried by individual manufacturing plants fluctuate in most cases over wide limits, and the instantaneous sum of the loads from a group of such plants will be always much less than the sum of the individual maximum loads. It has been found by electrical supply companies that except in special cases on the average the installed capacity or connected motor load of the individual plant expressed in horsepower should be divided by 2 in order to obtain the generator capacity in kilowatts required at the central station to supply its demand. It is important to keep in mind this distinction between "installed capacity" or "connected load" and the corresponding "demand" on the power system when considering industrial loads.



APPENDIX D-5.

ESTIMATE OF POWER REQUIRED FOR ELECTRIC OPERATION OF PENNSYLVANIA R. R., NEW JERSEY DIVISION.

The annual report of Pennsylvania Railroad gives the following figures regarding operations on the New Jersey division during 1917:

Freight:

Total miles of line.....	543
Number of tons carried (revenue).....	44,688,902
Number of tons carried (nonrevenue).....	2,780,614
Total	47,897,516

Freight—Continued.	
Net ton-miles (revenue)-----	2, 306, 287, 080
Net ton-miles (nonrevenue)-----	72, 502, 006
Total -----	2, 378, 789, 086
Total train miles-----	8, 474, 962
Average net load per train-----	tons 285. 10
Average net load per car-----	do 27. 41
Average miles each ton was carried-----	51. 67
Average number of loaded cars per train-----	24. 23
Average number of empty cars per train-----	10. 53
Passenger service:	
Total passengers carried-----	42, 398, 548
Total passenger miles-----	1, 038, 886, 989
Passenger train miles-----	9, 497, 840
Average distance traveled per passenger-----	miles 24. 49
Average number of passengers per car-----	23. 00

ESTIMATE OF POWER REQUIRED FOR FREIGHT HAULAGE.

The above figures show that the number of cars for the average train, including empties, is 34.76. The average weight for refrigerator cars, which may be taken as typical for the service, is approximately 22 tons.

Therefore the tare weight of the average train is-----	Tons. 764. 7
Weight of load for average train as above-----	685. 1
Total weight of average train-----	1, 450. 0

Total gross ton-mile for freight is $1,450 \times 3,474,962 = 5,038,694,900$ ton-miles.

The records for the electrified section of the New York, New Haven & Hartford Railroad where conditions are similar to this division show that 0.035 kilowatt hour per ton-mile of trailing load is for freight operations. Therefore the total power per year for New Jersey division would be $5,038,694,900 \times 0.035 = 176,354,321$ kilowatt hours.

If the freight movements were distributed uniformly the daily load on this basis would be 483,185 kilowatt hours.

On account of seasonal changes and other causes the maximum day which would determine generator capacities would be about double this figure, or 966,270 kilowatt hours.

ESTIMATE OF POWER REQUIRED FOR PASSENGER SERVICE.

From above data it appears that the average number of passenger cars per train is 4.7. Other statistics show that allowing for baggage and express cars the average number of cars per passenger train would be 6, each weighing about 50 tons with load, which gives 300 tons per train, exclusive of locomotives.

The total passenger ton-miles would, therefore, be $300 \times 9,474,840 = 2,849,352,000$ ton-miles.

The New York, New Haven & Hartford Railroad records for passenger service show that 0.055 kilowatt hour is required per ton-mile of trailing load.

Therefore the annual power for passenger service would be $2,849,352,000 \times 0.055 = 156,714,360$ kilowatt hours.

Sundays and holidays may be omitted in determining the power required for a typical day, which would be $156,714,360 \div 300 = 522,381$ kilowatt hours.

ESTIMATE OF MAXIMUM DEMAND ON SYSTEM.

It is not necessary to assume that the maximum freight and passenger demands would occur simultaneously, as the maximum traffic of the two classes come at different seasons. The maximum demand should therefore be estimated by combining the kilowatt hours for the maximum day for freight with the power for typical day for passengers as follows: $966,270 + 522,381 = 1,488,651$ kilowatt hours.

Under these conditions the load factor should be approximately 50 per cent.

Thus giving a maximum demand of $1,488,651 + (24 \times 0.5) = 124,054$ kilowatts.

APPENDIX D-6.

ESTIMATE OF POWER REQUIRED FOR COAL MINES—ANTHRACITE DISTRICT.

[Data taken from report of Department of Mines for Pennsylvania for 1916.]

No. of district.	Operating companies.	Tons (2,240) production.	Tons used for heat and power.	Water pumped to surface (gallons per minute).	Boilers (horse power capacity).	Generators (kilowatt capacity).	Days operation.
1.....	14	2,917,392	276,006	26,661	17,808	4,280	219
2.....	10	3,009,075	328,568	28,555	15,878	347	230
3.....	5	2,950,329	284,552	21,378	13,190	225	228
4.....	8	2,578,967	171,182	15,835	10,195	1,659	219
5.....	8	3,043,089	99,104	13,505	8,414	7,130	233
6.....	8	3,297,518	273,232	42,200	17,602	3,508	215
7.....	5	2,804,335	192,469	29,970	14,725	2,275	275
8.....	4	3,756,826	347,999	27,250	21,768	3,920	232
9.....	7	2,904,386	328,403	32,199	23,468	2,446	254
10.....	10	2,500,360	166,755	17,930	17,445	235	245
11.....	4	3,235,034	273,302	16,702	17,149	3,475	221
12.....	6	3,736,665	532,913	12,675	21,649	2,603	255
13.....	6	3,492,962	242,583	26,244	18,163	2,800	239
14.....	7	3,478,418	368,338	16,184	22,122	4,059	207
15.....	9	4,086,028	499,064	38,268	34,720	1,520	272
16.....	11	3,050,722	335,400	41,016	24,325	840	239
17.....	1	3,479,080	334,815	40,570	17,972	0	244
18.....	11	3,365,657	416,380	29,632	26,260	752	243
19.....	10	2,710,548	426,892	23,167	25,145	6,225	269
20.....	2	3,074,252	471,165	17,654	23,690	1,375	204
21.....	6	3,919,705	475,389	22,034	23,980	1,300	290
22.....	6	3,620,043	585,915	30,451	28,800	2,135	254
23.....	6	2,332,358	297,411	14,884	20,330	1,710	202
24.....	7	2,365,910	313,153	12,029	16,465	2,215	190
25.....	3	2,576,072	551,742	16,841	21,765	1,640	263
Total.....		78,285,891	8,393,727	614,874	499,493	58,349	1,235

¹ Average.

From a number of tests and investigations upon mines in this district, it appears that about 17 kilowatt hours is required per ton of coal produced and that the load factor should be about 40 per cent. On this basis the annual power requirements if all mines were electrified would be $17 \times 78,285,891 = 1,330,800,000$ kilowatt hours and the maximum load would be 380,000 kilowatts.

Amount of coal now used for power is approximately.....	Tons. 8,800,000
Amount required with electrification, allowing 2½ pounds per kilowatt hour....	1,500,000
Coal saved by electrification.....	6,800,000

APPENDIX D-7.

MISCELLANEOUS INDUSTRIAL LOAD—LEHIGH DISTRICT.

	Primary horse-power.		Value added by manufacturers, expressed in thousands.			
	1914	1909	1914	1909	1904	1909
Allentown.....	22,219	19,101	\$13,213	\$10,682	\$6,008	\$6,013
Bethlehem.....	2,485	3,086	1,526	1,362	1,980	1,800
Easton.....	7,272	5,965	6,686	3,491	2,375	2,232
Hasleton.....	3,334	3,112	2,323	2,006	1,066	706
Nanticoke.....	796	437	678	239	198	128
Plymouth.....	963	1,412	290	475	413	282
Pottsville.....	25,978	15,232	3,065	3,155	1,781	1,400
Scranton.....	24,994	20,564	12,923	12,063	9,200	7,532
Shamokin.....	2,706	1,862	1,986	1,415	418	447
Wilkes-Barre.....	11,867	12,109	8,720	7,093	5,785	4,308
Total.....	102,614	82,880	50,429	42,020	29,104	23,848

¹ No records; figures estimated from average for the district.

The above figures show an annual increase in primary power of 4,000 horsepower. Therefore the total power in 1917 should be approximately 124,000 horsepower connected load or 62,000-kilowatt demand.

Production of coal and cement—Lehigh district.

Year.	Coal.	Cement.	Year.	Coal.	Cement.
	<i>Tons (\$,000 pounds).</i>	<i>Barrels.</i>		<i>Tons (\$,000 pounds).</i>	<i>Barrels.</i>
1900.....	57,363,396	6,153,629	1909.....	80,223,333	24,246,706
1901.....	67,094,665	8,596,340	1910.....	83,683,994	26,315,359
1902.....	41,340,935	10,829,922	1911.....	90,917,176	25,972,108
1903.....	75,232,585	12,324,922	1912.....	84,426,869	24,762,083
1904.....	73,594,369	14,211,039	1913.....	91,226,964	27,189,601
1905.....	78,647,020	17,368,687	1914.....	91,189,041	24,614,933
1906.....	72,139,510	22,784,613	1915.....	89,377,706	24,876,442
1907.....	86,066,412	24,417,686	1916.....	87,680,198	24,105,381
1908.....	83,543,243	20,200,387	1917.....	99,611,000	24,423,507

APPENDIX D-8.

COST OF ELECTRICAL TRANSMISSION COMPARED WITH COAL TRANSPORTATION 150,000 KILOWATTS TRANSMITTED 80 MILES 150,000 VOLTS.

Cost of line, two independent tower lines, two circuits each, at \$12,500 per mile of single line.....	\$2,000,000
Step-up transformer substation at \$8 per kilowatt.....	1,200,000
Step-down transformer substation at \$8 per kilowatt.....	1,200,000

Cost of electrical transmission.

Operating costs:	
Transmission line—	
Patrolling 160 miles of line at \$125.....	20,000
Maintenance 160 miles of line at \$200.....	32,000
Substations—	
Maintenance and operation, two substations.....	80,000
Fixed charges:	
10 per cent of \$4,400,000.....	440,000
Losses, 10 per cent of generated power:	
150,000 kilowatts—75 per cent load factor—985,500,000 kilowatt hours.	
10 per cent—98,550,000 kilowatt hours at 5 mills.....	492,750
Total annual cost.....	1,014,750

Cost of transporting coal.

985,500,000 kilowatt hours—98,550,000—886,950,000 kilowatt hours.	
At 2½ pounds low grade anthracite per kilowatt hour—989,850 tons.	
At \$1 per ton difference in freight charges.....	989,850

Costs at 50 per cent load factor:	
Electrical transmission.....	\$850,500
Coal transportation.....	659,908
Difference in favor of coal transportation.....	190,600
Costs at 100 per cent load factor:	
Electrical transmission.....	1,179,000
Coal transportation.....	1,319,800
Difference in favor of electrical transmission.....	140,800

APPENDIX D-9.

PRIVATE ENGINEER'S ESTIMATE OF COST OF HYDROELECTRIC DEVELOPMENTS ON THE DELAWARE RIVER.

Land for reservoirs.....	\$1,884,000
Land for power sites.....	1,402,000
Existing power rights.....	500,000
Relocating Delaware & Eastern R. R.....	500,000
Relocating highways.....	850,000
Organization, etc.....	150,000
Dams for reservoirs.....	2,848,000
Hydraulic work for power plants.....	8,088,000
Turbines and electrical apparatus.....	4,878,000
Transmission lines.....	8,000,000
Substations.....	1,500,000
	24,095,000

Incidentals and engineering (10 per cent)-----	\$2,409,500
Interest during construction—6 per cent for 1½ years-----	28,504,500
	2,345,400
Contingent fund-----	28,849,900
	2,650,100
Total-----	31,500,000

Estimates are based upon concrete at \$5 per cubic yard, excavation of rock at \$2 per cubic yard and of earth at 60 cents per cubic yard. A liberal allowance has been made for building caissons and other structures required for construction purposes.

Since the estimate was made, the acquisition of the property has proceeded sufficiently far to indicate that the above allowances for land are ample.

APPENDIX D-10.

PRIVATE ENGINEER'S ESTIMATE OF COST OF PAUPACK DEVELOPMENT.

Drainage area-----	square miles-----	238
Gross head-----	feet-----	313
Average annual run-off-----	cubic feet-----	17,000,000,000
Capable of producing-----	kilowatt hours-----	90,000,000
Maximum run-off 47.2 inches—1889-----	do-----	140,000,000
Minimum run-off 22.4 inches—1913-----	do-----	64,000,000
Average used in this estimate-----	do-----	80,000,000
Dam 50 feet high makes reservoir 10 miles long by about 1 mile wide:		
Total capacity-----	cubic feet-----	8,500,000,000
Available storage-----	do-----	7,500,000,000
Cost—estimated, 1916:		
Dam, pipe line, and power house equipped for 40,000 kilowatts, exclusive of property-----		\$2,500,000
Step-up transformer substation, at \$8 per kilowatt-----		320,000
30 miles transmission line, single tower, two circuits, at \$12,000-----		360,000
		3,180,000
Cost per kilowatt, including transmission line-----	per kilowatt-----	79.50
Operation:		
Power plant—		
Labor and supplies-----		13,800.00
Maintenance, labor, and material-----		40,000.00
Transmission line, 30 miles, at \$350 per mile-----		10,500.00
Fixed charges:		
10 per cent of \$3,180,000-----		318,000.00
Total annual cost-----		382,800.00
Cost per kilowatt hour (delivered)-----	65,000 k. w. h.-----	5.8

APPENDIX D-11.

PRIVATE ENGINEERS' ESTIMATE OF COST OF CONOWINGO DEVELOPMENT, BASED ON 1917 CONDITIONS.

Earth excavations at \$1.00 per cubic yard-----	358,800
Rock excavations at \$2.00 per cubic yard-----	426,000
Concrete at \$8.00 per cubic yard-----	2,804,800
Railroad bridge with steel at \$0.06-----	248,500
Power-house building and hydraulic equipment, including five 34,800-horse-power turbines-----	2,713,300
Electrical equipment, including five 27,200 k. v. a. generators, fifteen 9,000 k. v. a. 110,000-volt transformers, with switchboards, etc., complete-----	2,070,000
Relocating railroad-----	2,005,000
	10,922,000
Engineering and contingencies, 15 per cent-----	1,638,300
Temporary structures during construction-----	450,000
Working capital-----	500,000
	13,510,300
60 miles of double-tower transmission lines at \$25,000-----	1,500,000
Step-down transformer substation, 100,000 k. w. capacity, at \$8.00 per k. w.-----	800,000
	15,810,300
Interest during construction, 6 per cent for 1½ years-----	1,422,900
Total-----	17,233,200

It is estimated that about \$3,000,000 additional will be required for property, franchises cost of promotion, etc. These have not been included, as it is assumed that payment can be made for them in secondary securities and not in cash.

APPENDIX E

Report to the Chief of Engineers, U. S. Army, dealing
with the Electric Power Problems in
the Southern States

Submitted by

CAPT. GEO. K. MILTENBERGER, Engineers, U. S. Army

CAPT. LYLE A. WHITSIT, Engineers, U. S. Army

CAPT. ROBERT W. LAMAR, Engineers, U. S. Army

MR. FREDERICK DARLINGTON, Consulting
(Formerly with the War Industries Board)

Washington, D. C., March 25, 1919

ELECTRIC-POWER PROBLEMS IN THE SOUTHERN STATES.

PREFACE.

1. The following report has been prepared to summarize the power situation in the States of Alabama, Georgia, Tennessee, North Carolina, and South Carolina (hereinafter referred to as the Southern States), as developed by the investigations of the Army Engineers assigned to service in the power section of the War Industries Board. It completes the information and conclusions reached in directing power service for war industries prior to the armistice on November 11, 1918, during which time they were informed concerning the power resources and limitations in this district, and contains recommendations for increasing the annual power supply for industries in these States to meet anticipated future requirements to an aggregate increase of 1,000,000,000 kilowatt hours within the next five to seven years.

This report covers the central station electric power generating and distributing systems and gives no details of the generation by isolated plants not connected to central station systems, concerning which there is no authoritative summary as to aggregate amounts of power or costs. The report recognizes that further centralization of the power supply in these States, with the discontinuance of isolated plants, is the economic and practical end to which power service should tend. This is now, and has been for some years, the trend of the times, and the power diverted from isolated plants to central systems will constitute a considerable portion of the estimated increase of central station service contemplated for the future as discussed in this report.

3. It is recognized that the resources in water, power, and fuel differ in the several States, that the demand for power in the various States is diversified as to nature and amount, and that the most economical and reliable service will be attained by developing the different resources according to their relative value and interconnecting these to make a unified and balanced system, utilizing in each instance the most available source of power without regard to existing individual ownership or State lines.

4. In preparing this report and the herein contained recommendations, it has been borne in mind that power delivered to points approximately central to the industrial power consuming sections, is of greater value and economic importance than power located remote from the industrial centers, which power requires for its utilization either long distance transmission lines or the creation of new industries to be built up around the centers of cheap power. Such new industries would be mostly of an electro-chemical or metallurgical nature and would afford only a relatively small return per unit of

power used, compared with the diversified and established industrial operations in the Southern States.

5. Central-station systems have met war needs in a superior way and have strikingly demonstrated the advantages of centralized service as compared with isolated-plant service. In cases of increased power requirements for war production, the central systems have far more rapidly than isolated plants, and with less demand on labor and material resources, increased their capacity to meet growing needs. Also they were better able to deliver their output to those particular points where the requirements of war industries necessitated. Since, for any additions to power supply for war needs in specific sections, they could draw upon the central system, even when necessary by the reduction of power supply to less essential users. This could not be done in the case of isolated plants equipped to serve only the specific factories and establishments for which they were constructed.

6. This report will consider only the question of power generation by interconnected power systems in the States above mentioned and will not concern itself with the matter of distribution to customers beyond the main generating plants, substations, and interconnecting trunk lines. The problem herein discussed has to do with steam and hydroelectric generation and the essential interconnection of generating stations to secure minimum capital cost and operating costs for power on main trunk-line systems connecting the generating plants and industrial centers. It is to be noted that a very large additional expenditure, not included in this discussion, is necessary to distribute power from these generating plants and trunk lines to power consumers, and it is observed that frequently the cost of distribution from the trunk lines to the consumers exceeds the cost of generation and the trunk-line expenses.

7. Uncertainty exists concerning the future cost of labor and material for engineering works necessary for developing power. For the purpose of comparing the cost of these developments in the different States, the cost has been figured as near as may be upon the prewar cost plus 40 per cent. This is much less than the cost of such works during the past year and at the present time, but for comparative purposes, and as the result of careful examination, is adopted as a reasonable estimate for future work covering a period of five years.

8. The report first describes the power systems of the Southern States as they existed prior to the armistice, and the conditions under which service was rendered during the war; second, there are mentioned certain additions and improvements which are now being made, contemplated, or recommended for better economy and reliability of supply and service to the existing industries; third, recommendations are made for additional power developments to meet a future demand of 1,000,000,000 kilowatt hours, more or less, over the present demands, and also for complete interconnection of the existing power systems and future developments; and, last, there is included a discussion of the advantages to be gained by a thorough interconnection of the power systems, of the advisability of joining the Muscle Shoals power with that of the combined system, and of the effect of interest charges on the cost of power.

SUMMARY.

9. This report states briefly the power requirements of the Southern States and the conditions under which this power is now supplied, and makes recommendations for improving and increasing power generation to provide for public and private needs. The requirements are now supplied partly by central station electric systems, which serve diversified industries, and partly by isolated steam or water power plants built and operated individually for specific factory or other needs. In the interest of economy, reliability, and conservation, isolated plant generation should be discontinued and central power substituted. Industrial development in these States and the conversion of isolated plant service and improvement of power supply will require within the next five to seven years, according to approximate estimates, 1,000,000,000 kilowatt hours increase in annual production, of which 800,000,000 kilowatt hours is allocated to the Carolinas and 700,000,000 kilowatt hours to the States of Tennessee, Alabama, and Georgia.

10. The investigation made for the purpose of this report does not include a conclusive investigation of the power resources in the Carolinas. With the data at hand we are unable to indicate that the Carolinas have any natural resources in hydro power or other sources that are suitable for the creation of this new power on a basis that would compare favorably with the production by a proposed tri-State interconnected system as described for Alabama, Georgia, and Tennessee, and it appears probable that a large part of the additional power required in the Carolinas could be more economically derived from the interconnected system of these three States. If the anticipated increase for the Carolinas is derived from these three States, the developments recommended for the latter will have a sufficient excess generating capacity to supply the Carolina requirements.

11. There are certain large hydro developments that have been constructed and others that are projected in Tennessee and North Carolina by private interests for the purpose of manufacturing aluminum. These developments and projects have not been considered in this report as part of the proposed interstate power system for the reason that the resources and requirements of the private aluminum manufacturing interests are not set forth with sufficient assurance regarding future conditions to permit of establishing a measure of the value of their resources in combination with interstate transmission lines. Unquestionably, if an interstate combination is built up as described and recommended in this report, benefit will accrue both to the aluminum manufacturing concern and to the interstate systems if interchange of power is arranged for.

12. In estimating the additional power service that can advantageously be rendered by the central station systems account has been taken of the established central station business and the reasonable expected increase in going industries. Provision has not been made in these recommendations for extraordinary additions to the power service to provide for a large new electrochemical undertaking or for railroad electrification. One billion kilowatt hours increase, as described, is the foreseen requirements without these new industries of electrochemical and railroad electrification.

13. The major central station systems at present in operation in the States of Alabama, Georgia, and Tennessee have an aggregate prime generating capacity estimated at 1,230,000,000 kilowatt hours annually, and it is estimated that the central station output should be increased by 700,000,000 kilowatt hours annually to provide for the conversion to central station service of power now being generated by isolated plants and for normal industrial growth anticipated within the next five to seven years.

14. As the best means of increasing the aggregate capacity of the central power systems of the three States and to improve economy and reliability, it is recommended that the major power systems now in these States be effectively interconnected by transmission lines and the best available resources for hydro and steam power be developed to increase the interstate combined system.

15. An examination of the central power systems for 1919 conditions shows that these systems, when operated individually, have an aggregate generating capacity capable, under commercial conditions, of producing 1,230,000,000 kilowatt hours of prime power annually, of which 13 per cent, or 163,000,000 kilowatt hours, in seasons of normal river flow would have to be produced by steam plants, requiring a consumption of 190,000 tons of coal annually. By effectively interconnecting these systems and operating them for the best joint economy the capacity of the combined systems would be increased to 1,370,000,000 kilowatt hours annually, requiring, in years of normal river flow, the production of 132,000,000 kilowatt hours by steam, with a consumption of 140,000 tons of coal. An increase of 140,000,000 kilowatt hours in the generating capacity is effected by complete interconnection and joint operation, as above, which in itself is an important reason for interconnection.

16. In building for increased power production needed to convert isolated plant service to central station operation and to provide for industrial growth, the proposed interstate interconnected power system affords a marked advantage over the present plan of independent disconnected or inadequately interconnected systems, particularly as the interconnected systems would permit the use of the most economical sources of power within the area of the proposed interstate system, regardless of the relative location of these sources to localized market centers.

17. Contemplating the adoption of this plan, and in order to provide increased power facilities for the production of 700,000,000 kilowatt hours annually (the estimated requirements for isolated plant conversion and industrial growth within the next five to seven years), it is recommended that the hydroelectric plants be built on the Tallapoosa River, Ala., near Cherokee Bluff, together with a large storage reservoir. The present power systems combined with the proposed Tallapoosa plants would have a generating capacity of 2,100,000,000 kilowatt hours annually, which is an increase of 730,000,000 kilowatt hours over the capacity of the present systems if interconnected and jointly operated.

18. Building for increased power production in the three States under consideration should not, and will not, cease with the installation of 700,000,000 kilowatt hours increase in annual capacity. It is anticipated that with this increase provided for during the next

five to seven years, still further increased capacity should be undertaken for growth following the five-year period, and the recommendation of Tallapoosa is made with a view to later additions to the generating capacity of an interstate power system for Alabama, Georgia, and Tennessee, and possibly the Carolinas. Developments which compare favorably with the Tallapoosa project have been examined and considered—

(a) On the Chattahoochee River, at Bartletts Ferry, in western Georgia, for increasing the capacity of the interstate system by 170,000,000 kilowatt hours annually.

(b) Two developments, referred to as Tugaloo and Mathis, on the Tugaloo River, in northeastern Georgia, for increasing the capacity of the system by 240,000,000 kilowatt hours annually.

19. A large number of other developments, including steam plants at coal-mine centers, were examined and compared, but considered less favorable than those mentioned above as components of the power system composed of the present central station systems adequately interconnected.

20. The great advantages of interconnection and joint operation of power systems, and the economies in building for increase in generating capacity, as herein stated, apply equally to a combination of the privately owned power companies with the Government powers now building at Muscle Shoals. The characteristics of this Government power and the gain, both to the Government power and to the privately owned powers that would result from interconnection and exchange of facilities, was an important consideration in the recommendation of the Tallapoosa River project, inasmuch as the interstate combination, with other power substituted for Tallapoosa, might be quite as favorable as the Tallapoosa powers in a combination without Muscle Shoals.

21. Under the present laws, the Government Muscle Shoals hydro power now building can not be connected to or operated in conjunction with private interests.

22. The Government hydro power at Muscle Shoals will be on a variable river with opportunity for the development of a vast amount of second-class, or 9 months power, and a relatively small proportion of 12 months, or primary power. A Government-owned steam plant being built at Muscle Shoals will be capable of converting a portion of the second-class power into prime power, but it can not do so as economically as the combination with the proposed interstate power system, because if steam plant auxiliary power is to be used with the Muscle Shoals power, other steam plants already constructed are more favorably situated than the Government steam plant for furnishing the bulk of this supplementary steam power.

23. Still further if the Government needs do not require the entire output of the Muscle Shoals plants, it would be a criminal waste to deprive the industries of Alabama and adjacent States of this supply of power. We want to emphasize that an interconnected power system, as herein recommended, is the best possible vehicle for taking over such part of Muscle Shoals power as the Government may not require for its own uses, and delivering it to the Southern States industries, and that to make provision for doing

this efficiently, such use of the surplus power should be arranged for at a very early date, and considered in connection with private plant developments to the end that these developments may be of a character that will advantageously supplement Muscle Shoals.

24. It is recognized that the resources for cheap power in the Southern States are one of their most valuable assets industrially, and Muscle Shoals hydro power has long been looked upon as a favorable project, particularly in combination with Tennessee River improvements for navigation, and prior to the war a private corporation even went so far as to spend some hundreds of thousands of dollars in securing property rights and exploring foundations and making designs. It appears that with an exchange of power between the Government interests and private power systems, maximum economy will result to both interests, whereas, if the present law is enforced, the Government will lose the economic advantage of interchanging power with existing privately owned systems and the southern industries will be deprived of the benefit of Muscle Shoals power.

25. The proposed interstate power system above described including the proposed Tallapoosa River developments, and capable, as stated, of producing 2,100,000,000 kilowatt hours of prime power annually, if combined and operated in conjunction with a hydro plant at Muscle Shoals with 300,000 kilowatts ultimate installed capacity as proposed, would be capable of producing, in years of normal river flow, 2,880,000,000 kilowatt hours annually of prime hydro power without any steam generation.

PART 1.

DESCRIPTION OF PRESENT CENTRAL STATION SYSTEMS.

INSTALLED CAPACITY.

26. In the Southern States at the outbreak of the war, the bulk of the power used by industries in the States was produced by a few large power generating and distributing systems extending through the principal manufacturing centers.

27. The following is a tabulation of the generating capacity and the production of these power systems by States during 1917 and 1918:

State and company.	Total installed generating capacity.		Total power generated.	
	Hydro.	Steam.	1917	1918
Alabama:	<i>K. V. A.</i>	<i>K. V. A.</i>	<i>Kilowatt hours.</i>	<i>Kilowatt hours.</i>
Alabama Power Co.	69,000	30,000	288,300,000	394,749,827
Government unit in the Warrior plant ¹		30,000		
Birmingham Railway, Light & Power Co. ²		10,000		
	69,000	70,000		
Georgia:				
Georgia Railway & Power	78,100	15,500	236,481,800	206,850,000
Central Georgia Power Co.	18,000	4,500	59,147,000	55,482,500
Columbus Power Co.	21,650	1,500	83,569,000	85,987,787
	117,750	21,500	379,177,000	347,280,287
Tennessee:				
Tennessee Power Co.	88,625	38,700	547,900,000	519,959,383
North and South Carolina:				
Southern Power Co.	142,800	29,800	461,600,000	487,350,100
Carolina Power & Light Co.	35,000	4,925	85,700,000	91,109,500
	177,800	34,725	547,300,000	578,459,609
Total	448,175	162,925	1,762,677,000	1,840,449,097

¹ Completed in December, 1918.

² Effective capacity available by contract.

GENERATING CAPACITY.

STATE OF ALABAMA.

28. The following was the central station power generating capacity in the State of Alabama during the year 1917 and up to November 11, 1918.

29. *The Alabama Power Co.* with an interconnected system operated generating plants at—

	Kilowatts.
Lock 12, water power, Coosa River, 5 units, installed capacity	67,500
Jackson Shoals water power, installed capacity	1,500
Gadsden steam plant, installed capacity	10,000
Warrior River steam plant, installed capacity	20,000
In Birmingham, a steam plant available by contract relations, efficient installed capacity	10,000

Total efficient installed capacity

109,000

NOTE.—Since the armistice (completed in December, 1918), the Government has installed a 30,000-kilowatt steam turbine generator at the Warrior plant of the Alabama Power Co.

30. In order to unify the above described generating plants, and complete a generating system capable of the best utilization of the hydro plants in combination with steam plants, the Alabama Power Co. had in operation, prior to the armistice, a system of double-circuit high-tension transmission lines of 110,000 volts, through Gadsden, Anniston, Jackson Shoals, and Sylacauga to Lock 12, and from Lock 12 to Birmingham and a 110,000-volt single-circuit high-tension line from Jackson Shoals through Birmingham to Warrior steam plant. They also had 100,000-volt substations installed at various points, aggregating approximately 96,600 kilovolt-amperes capacity.

31. Under operating conditions for 12 months' service, figuring the output of Lock 12 at 250,000 kilowatt hours daily at extreme low-water stage, and including a 30,000-kilowatt generator recently completed by the Government at the company's Warrior steam plant, but allowing reserve for emergency or break-down service, the prime capacity of this system is 80,000 to 90,000 kilowatts. At 80,000 kilowatt peak this system is capable of serving the industries within its transmission area with 385,000,000 kilowatt hours annually under practical commercial conditions, which we have established for the purpose of this report at 55 per cent annual load factor. (See Appendix 1.)

NOTE.—In order to generate 80,000 kilowatts, as above, with the present system, Lock 12, plant on the Coosa River, must be operated on daily peak loads, holding back water at certain hours daily and discharging it rapidly at other hours. To avoid detriment to navigation it would be necessary to construct a regulating dam at a cost of \$119,000 (using the cost estimate basis of this report, \$85,000 on prewar costs, plus 40 per cent).

NOTE.—During the year 1918, prior to the completion of the 30,000-kilowatt Government unit at the company's Warrior steam plant, and under war emergency conditions, with abnormally high-load factors due to electrochemical and metallurgical operations, the output of this system was 395,000,000 kilowatt hours without the 33,000 kilovolt-amperes Government unit at Warrior, but with unusually favorable water stages at Lock 12, while the nitrate plant at Muscle Shoals was taking power during November and December.

32. For service in Alabama, to continue the present business of the Alabama Power Co. and expand the service under anticipated commercial conditions, up to a load of 80,000 kilowatts and an annual output of 385,000,000 kilowatt hours, as above described (annual load factor of 55 per cent), it is estimated that the amount of power generated per month during the year will vary according to seasons and business conditions between 29,000,000 kilowatt hours and 36,000,000 kilowatt hours (the average monthly consumption being 32,100,000 kilowatt hours to make 385,000,000 kilowatt hours annually).

NOTE.—The maximum variation in the monthly kilowatt-hour output, exclusive of electrochemical load, of the Alabama Power Co. between the maximum month and minimum month was 22 per cent in 1917 and 14 per cent in 1918.

33. In one full year's operation under average river conditions we estimate that the kilowatt hours generated by water at Lock 12 will be 275,000,000 kilowatt hours, and the kilowatt hours generated by steam supplement will be 110,000,000 kilowatt hours; total, as above, 385,000,000 kilowatt hours.

34. For this annual production, for maintaining steam plants for auxiliary service, for emergency reserve, and for voltage and power

factor regulation we estimate that the annual coal consumption will be 115,000 short tons.

35. *Montgomery Light & Water Power Co.*—This is one of the two companies serving Montgomery and immediately adjacent district. It has a water-power plant with an installed capacity of 5,825 kilo volt-amperes on the Tallapoosa River about 29 miles northeast of Montgomery. In addition it has a steam plant with 2,000 kilowatt capacity in Montgomery connected with the water-power plant by a 33,000-volt transmission line. This steam plant is used as a stand-by for the hydrodevelopment and is run only during low water or in emergencies.

36. During 1917 the combined output of these two plants was 24,572,000 kilowatt hours, 3,184,000 being by steam. In 1918 the total was 25,298,000 kilowatt hours, 1,897,000 by steam, with a peak load of 4,800 kilowatts. The system capacity is estimated at 5,000 kilowatts. The coal consumption was 13,500 tons in 1917 and 7,300 tons in 1918.

37. *Montgomery Light & Traction Co.*—This company operates the street railway system and also gives electric service in Montgomery from a steam plant located in the city, which has an installed capacity of 5,000 kilowatts. It generated for both railway, light, and power requirements 12,275,000 kilowatt hours in the year 1917 and 16,292,000 kilowatt hours in 1918, with a peak load of 3,500 kilowatts. The coal consumption in 1917 was 21,600 tons and in 1918 amounted to 32,400 tons.

38. The steam plant of the company is more modern and efficient than the one owned by the Montgomery Light & Water Power Co. and is capable, with small improvement, of serving the steam plant requirements of both companies. There is, however, no interconnection between the plants of the two companies. The power-consuming industries in and around Montgomery are not greatly varied in nature and are increasing but slowly.

39. *Tallassee Falls Manufacturing Co.*—About 5 miles below the water-power development of the Montgomery Light & Water Power Co. the Tallassee Falls Manufacturing Co. have developed a falls on the Tallapoosa River for the mechanical drive of cotton mills with an installation of 5,235 horsepower in water wheels. Their load is about 3,000 horsepower. Should this site be developed for hydroelectric power it is estimated that by the time such development would be completed their demand would be 3,400 kilowatts, with an annual consumption of 7,300,000 kilowatt hours.

40. *Mobile Light & Railroad Co.*—This company operates a steam plant of 2,350 kilowatts capacity in direct current for the street railway system of the city and supplies no light or power business. It generated 5,301,000 kilowatt hours in 1916, with a peak demand of 2,000 kilowatts, and about the same in 1917. The coal consumption approximates 13,000 tons per year.

41. *United States Steel Corporation.*—The Chicasaw Utilities Co., controlled by the United States Steel Corporation, will some time during the summer of 1919 have in operation about 5 miles from Mobile a new modern steam plant having two 4,000-kilowatt steam turbines for supplying the power needs of a new shipbuilding plant and industrial village. Included in this service will be an electric

street car line, waterworks, and residential and street lighting system. It appears that the service for the village is to be furnished from this plant because the local utility companies in Mobile were not in position to extend such service.

42. *Mobile Electric Co.*—This company operates a steam plant of 6,195 kilowatt installed capacity in the city of Mobile and generated 10,962,000 kilowatt hours in 1917 and 15,255,000 kilowatt hours in 1918, with a peak demand of 4,200 kilowatts. The coal consumed in 1917 was 22,000 tons and 34,400 tons in 1918. The only industries of appreciable size served with power are shipbuilding plants and the terminal yards of the Mobile & Ohio Railroad.

43. The above constitute all the major power systems of Alabama, the remainder being small systems of a purely local character, none of which by reason of surrounding conditions will ever become an important generating center. (See Appendix 4.)

STATE OF GEORGIA.

44. *Georgia Railway & Power Co.*—This company with an interconnected system operated generating plants during the years 1917 and 1918 as follows:

<i>Installed capacity.</i>		Kilowatts.
Tallulah Falls and Mathis Reservoir, water power, five units.....		62,500
Morgan Falls (25-cycle), water power.....		10,000
Chestatee, water power.....		720
Dunlap, water power.....		1,700
Butler Street (3,500-kilowatt unit, 25-cycle), steam plant effective.....		5,000
Davis Street, steam plant effective.....		5,000
Galnesville, steam plant effective.....		186
Carrollton, steam plant effective.....		125
Total effective installed capacity.....		85,231

NOTE.—The two last-named steam plants, aggregating 301 kilowatts capacity, are inefficient and are disregarded in future estimates.

NOTE A.—The Georgia Railway & Power Co. operates at 60 cycles, except Morgan Falls hydro plant and one steam unit at Butler Street, which are 25 cycle and operate through rotaries to direct-current railway load and through frequency changers with the 60-cycle load.

45. Of the above plants, Tallulah Falls hydroelectric station is the main generating source of this company. It is connected with a central high-tension distributing substation near Atlanta by a double circuit, 110,000-volt transmission line, 90 miles long. The central substation, together with two smaller ones, aggregate some 46,500 kilo volt-amperes and constitute the high-tension substation capacity for distribution of the power from Tallulah Falls to the distribution lines of the Georgia Railway & Power Co. At the Tallulah Falls plant there is a transformer capacity of 20,000 kilo volt-amperes set aside for delivering power to the 100,000-volt lines of the Southern Power Co. operating in North and South Carolina. The total 110,000-volt substation capacity may therefore be rated at 66,500 kilo volt-amperes.

46. The other generating plants of the company do not tie into the high-tension 110,000-volt system. They feed directly into the distribution system, which is also fed from the main high-tension substation served from Tallulah Falls.

47. The lines of the company interconnect with those of the Tennessee Power Co. with substation capacity of 1,500 kilo volt-amperes with those of the Columbus Power Co. with substation capacity of 1,500 kilo volt-amperes, with those of the Central Georgia Power Co. with substation capacity of 9,000 kilo volt-amperes, and also the Southern Power Co. as mentioned previously. With the exception of that to the Southern Power Co., the interconnections are merely the meeting of two distributing lines and their capacity for interchange of power between generating sources is limited by the low operating voltage and the necessity for serving customers along the lines. The lines are so designed, however, as to make it a comparatively easy matter to change them over to 110,000-volt transmission trunk lines with separate service lines for customers when conditions warrant.

48. With the present development and with additional storage capacity now being built at the Burton Reservoir on the Tallulah River (see Part 2 under Georgia), scheduled for completion in July, 1919, and allowing a reasonable reserve for emergency or breakdown service, the prime capacity of this system in dry years under ordinary commercial conditions (established for the purpose of this report at 55 per cent annual load factor, as described in Appendix A for the interconnected group of Southern States) is 52,000 kilowatts, with an annual output of 250,000,000 kilowatt hours.

NOTE.—In a year of average stream flow the system would have a generating capacity of 275,000,000 kilowatt hours.

NOTE.—The Georgia Railway & Power Co. estimates the capacity of their system in dry years, including Burton Reservoir, at 40 per cent annual load factor, at 71,600 kilowatts with an annual output of 250,000,000 kilowatt hours of hydro power alone.

NOTE.—For the year 1917 the actual power generated by the Georgia Railway & Power Co. was 236,461,000 kilowatt hours. They purchased 22,146,000 kilowatt hours from adjacent systems and sold 76,954,000 kilowatt hours to adjacent systems, leaving a net delivery to their own system of 181,653,000 kilowatt hours, with a peak of 52,200 kilowatts or an annual load factor for their system of 39.7 per cent.

NOTE.—For the year 1918 the actual power generated by the Georgia Railway & Power Co., before completion of the 5,000,000,000 cubic foot reservoir, was 205,850,000 kilowatt hours. They purchased 32,640,000 kilowatt hours from adjacent systems and sold 29,414,000 kilowatt hours to adjacent systems, leaving a net delivery to their own system of 209,076,000 kilowatt hours, with a peak load of 58,000 kilowatts, or an annual load factor of 41.1 per cent.

49. *Central Georgia Power Co.*—This company operates an interconnected power system with one hydroelectric plant on the Ocmulgee River near Lloyds Shoals and two small steam plants at Macon. During the years 1917–18 these plants had installed the following generating capacity:

	Kilowatts.
Lloyds Shoals, water power plant.....	18, 000
No. 1, steam plant effective.....	1, 500
No. 2, steam plant.....	1, 500
	<hr/> 21, 000

50. The above plants are connected by 66,000-volt circuits and the main transmission is at 66,000 volts, of which there are 98 miles of double circuit line and 37 miles of single circuit line.

51. The system connects with that of the Georgia Railway & Power Co. near Atlanta where the Central Georgia Power Co. has a 9,000-kilo volt-ampere substation connecting its 66,000-volt line with the low-tension distribution circuits of the Georgia Railway & Power Co. The capacity for interchange of power is limited by the existing load on the distribution circuits of the latter company.

52. During a year of average river flow, and allowing a reasonable reserve or break-down capacity, the above plants have a prime generating capacity of 65,000,000 kilowatt hours which is equivalent to a maximum peak load of 18,500 kilowatts on an annual load factor of 55 per cent. (See Appendix 7.) In an average year this power would be produced as follows: By steam, 6,500,000 kilowatt hours; by water, 58,500,000 kilowatt hours.

NOTE.—In 1917 the company generated 3,328,600 kilowatt hours by steam and 55,822,150 kilowatt hours by water with an annual load factor of 34.4 per cent. In 1918 the company generated 8,962,600 kilowatt hours by steam and 46,499,900 kilowatt hours by water with an annual load factor of 34 per cent.

53. *Columbus Power Co.*—This company with an interconnected system operates three hydroelectric plants on the Chattahoochee River near Columbus, Ga., and one steam plant in Columbus. These plants had installed the following capacity in generating equipment during 1917 and 1918:

	Kilo volt-amperes.
Goat Rock, water power plant.....	13,750
North Highlands, water power plant.....	6,900
City Mills, water power plant.....	1,000
Columbus, steam plant.....	9,000
Total.....	30,650

NOTE.—The steam plant at Columbus had only 1,500 kilo volt-amperes capacity until the last part of 1918 when an additional unit of 7,500 kilowatt capacity was installed.

54. The Goat Rock plant and the steam plant are connected into the 66,000-volt transmission system which extends up the Chattahoochee Valley with a total length of about 53 miles. The other two plants as well as the steam plant feed into the low tension system which distributes power in the vicinity of Columbus.

55. The transmission system connects with that of the Georgia Railway and Power Co. at Newnan, Ga., through a low-tension distribution circuit. Both companies have substations at the end of their high tension systems for the purpose of serving customers and these stations are connected on the low tension side. The capacity for transfer of power is limited by the installation of the Georgia Railway and Power Co. station of 1,500 kilo volt-amperes.

56. During a year of average river flow and allowing a reasonable reserve or break-down capacity, the above plants have a prime generating capacity of 120,000,000 kilowatt hours, which is equivalent to a maximum peak load of 25,000 kilowatts on an annual load factor of 55 per cent. In an average year this power would be produced as follows: By steam, 10,000,000 kilowatt hours; by water, 110,000,000 kilowatt hours.

57. With the full installation of 9,000 kilo volt-amperes in the steam plant, the system has generating capacity to maintain the out-

put of 120,000,000 kilowatt hours in a year of low flow by the generation of a considerable amount of steam power.

NOTE.—In 1917 the company generated 83,300,000 kilowatt hours by water and 269,000 kilowatt hours by steam.

NOTE.—In 1918 the company generated 85,558,000 kilowatt hours by water and 409,669 kilowatt hours by steam.

58. *Augusta-Aiken Railway & Electric Corporation.*—This company operates a general lighting, power, and street railway business in Augusta, Ga., and transmits power about 18 miles to Aiken, S. C. The main generating station is a hydroelectric plant on the Savannah River about 8 miles north of the city of Augusta, and has an installed capacity of 13,500 kilo volt-amperes. The dam and power house substructure have been laid out for an ultimate development of double this capacity. Should additional storage be obtained on the upper stretches of the river at some of the developments of the Georgia Railway & Power Co., it would seem advisable to increase the installation at this plant.

59. The company also has a steam plant of 2,750 kilo volt-amperes installed capacity in Augusta, used as a stand-by. Previous to 1917 the plant had not been run for several years, but the increase loads of 1917 made it necessary to put it into service for a time and the low water conditions of 1918 made its use necessary to a larger extent. The Augusta-Aiken Railway & Electric Corporation has a plant on Augusta Canal with 676 kilo volt-amperes capacity in 600 volt direct-current equipment for the street railway system. Contracts for water from this canal for several mills precede the rights of the power company, consequently during low water this direct-current plant usually must shut down.

60. The Savannah River hydrostation generated 36,592,500 kilowatt hours in 1917, and 38,815,810 kilowatt hours in 1918, the annual load factors being 43.2 and 41.6 per cent, respectively. The average daily week-day load factor was 75 per cent during 1918. The steam plant in Augusta generated 17,875 kilowatt hours in 1917 and 254,875 kilowatt hours in 1918, using 890 tons coal in 1918. The hydro-plant on the canal generated 2,305,750 kilowatt hours in 1917 and 2,566,160 kilowatt hours in 1918.

61. *Savannah Electric Co.*—This company is the larger of two companies serving general power and lighting business in Savannah. It also operates the street railway system. It owns two steam plants in the city, the larger or main plant, the Riverside station, having 10,000 kilo volt-amperes installed generating capacity, while the smaller plant, the Indian Street station, has 1,500 kilo volt-amperes capacity, and, due to its inefficiency, is used as a stand-by and emergency only. The peak load on the system was 8,700 kilowatts in 1918, the generation at Riverside station in 1917 was 30,783,790 kilowatt hours, using 32,306 tons of coal, and 36,438,270 kilowatt hours, using 37,706 tons of coal in 1918. Indian Street station generated 16,020 kilowatt hours using 107 tons coal in 1917 and 1,482,690 kilowatt hours, using 3,450 tons coal in 1918. Some shipbuilding and fertilizer works added largely to their load in 1918. The annual load factor in 1917 was 47.1 and in 1918 50.2 per cent. The average daily week-day load factor was 72 per cent.

62. *Savannah Lighting Co.*—This is the smaller of the two companies serving general lighting and power business in Savannah, and

has one steam plant of 6,500 kilo volt-amperes installed generating capacity; the load on the station, however, has been much under its capacity and has been decreasing during the past few years, as shown by the following:

Year.	Kilowatt hours gener- ated.	Kilowatt peak.	Annual load factor.	Tons coal used.
1916.....	9,711,100	2,900	<i>Per cent.</i> 38.2	11,223
1917 (partly estimated).....	8,456,000	2,200	43.6	11,460
1918.....	8,166,540	1,900	49.0	10,975

63. The foregoing constitute all the major power systems of Georgia, the remainder being small systems of a purely local character, none of which by reason of surrounding conditions will ever become an important generating center. (See Appendix 4.)

STATE OF TENNESSEE.

64. The following is a statement of the central station power generating capacity in the State of Tennessee during 1917 and 1918.

65. *Tennessee Power Co.*—This company with an interconnected system operated generating plants as follows:

	Kilowatts
Hales Bar, water power, installed capacity.....	40,500
Great Falls, water power, installed capacity.....	9,375
Ocoee No. 1, water power, installed capacity.....	18,750
Ocoee No. 2, water power, installed capacity.....	15,000
Parksville, steam plant, effective installed capacity.....	15,000
Nashville, steam plant, effective installed capacity.....	13,000
Knoxville, steam plant, effective installed capacity.....	4,500
Chattanooga, steam plant, effective installed capacity.....	1,500
	117,625

NOTE.—Chattanooga steam plant is practically obsolete and so inefficient that it is not given further consideration in this report.

66. In order to utilize these plants to the best advantage and to serve the territory, the company had in operation a system of single circuit, 120,000-volt transmission lines from Parksville to Nashville and Maryville and Hales Bar, via College Junction, or a total length of 256.5 miles, and also had 66,000-volt connections between the other plants with a total length of 166.5 miles.

67. The company has an interconnection with the Georgia Railway & Power Co., which is limited for interchange of power by a transformer capacity of 1,500 kilo volt-amperes. The lines of the Georgia Railway & Power Co., as explained in Part 1, are also a limiting feature. The company also connects with a generating station of the Aluminum Co. of America, which is the principal load of the Tennessee Power Co.

68. During a year of average river flow and allowing a reasonable reserve or break-down capacity, the prime generating capacity of the above plants is 385,000,000 kilowatt hours annually, which is equivalent to a maximum peak of 80,000 kilowatts at 55 per cent annual load factor. (See Appendix 1.)

NOTE.—In 1917 the company actually generated 547,900,000 kilowatt hours with an annual load factor of 75 per cent. In 1918 the company actually generated 519,969,883 kilowatt hours with an annual load factor of 67½ per

cent. During both these years the bulk of the power was supplied to the Aluminum Co. of America whose load is of an electro-chemical nature, with extremely high load factor and which can be varied in amount to meet the changes in river flow from wet to dry season.

69. During an average year, as described above, it is estimated that in producing 385,000,000 kilowatt hours of prime power 373,000,000 kilowatt hours would be produced by water and 12,000,000 kilowatt hours by steam plants. In a year of extreme low water the corresponding figures would be 345,000,000 kilowatt hours of water power and 40,000,000 kilowatt hours of steam power.

70. Although only one of the power systems of the State of Tennessee has been considered, and although there are other important smaller central station systems in the State, yet it generates 83.5 per cent of the total central station power. (See Appendix 4.)

STATES OF NORTH AND SOUTH CAROLINA.

71. The following is a statement of the generating capacity of the major central station power companies in these States during 1917 and 1918.

72. *Southern Power Co.*—This company, with an interconnected system, operated generating plants as follows:

	Kilowatts.
Lookout Shoals, water power, installed capacity-----	21, 000
Catawba, water power, installed capacity-----	6, 000
Fishing Creek, water power, installed capacity-----	30, 000
Great Falls, water power, installed capacity-----	24, 000
Rocky Creek, water power, installed capacity-----	24, 000
Ninety-nine Islands, water power, installed capacity-----	18, 000
*Idols, water power, installed capacity-----	1, 300
*Saluda, water power, installed capacity-----	2, 700
*Portean Shoals, water power, installed capacity-----	7, 500
*Gregg Shoals, water power, installed capacity-----	1, 250
Greenville, steam plant, effective installed capacity-----	8, 000
Greensboro, steam plant, effective installed capacity-----	8, 000
Mount Holly, steam plant, effective installed capacity-----	8, 000
Eno, steam plant, effective installed capacity-----	10, 000
*Anderson, steam plant, effective installed capacity-----	850
	<hr/> 171, 600

NOTE.—Those plants marked with (*) indicate plants operated by Southern Public Utilities Co., which also purchases power from the Southern Power Co.

73. For economic utilization of these generating sources and to serve a very large territory, the company has an extensive network of transmission lines, consisting of 571 miles of 88,000 volt pole and tower lines and 626 miles of 44,000 volt principally pole lines.

74. The company has interconnection with the Carolina Power & Light Co. near Raleigh, with the Georgia Railway & Power Co. at Tallulah Falls, as previously described, and with the Tallassee Power Co. (Aluminum Co. of America) at Badin, N. C. The first two interconnections are with companies with slightly different operating voltages, which renders it inadvisable to operate in parallel, and the usual method of interchange is to divide the bus in one of the power houses and operate specific units at the interchange voltage. The capacity at Raleigh is 4,000 kilowatts and that at Tallulah Falls normally 20,000 kilowatts. The interconnection at Badin Falls amounts to approximately 9,000 kilowatts and has to be effected by

means of rotary converters through the direct-current bus, as the two systems are of different frequency.

75. The company is building and has practically complete a large storage reservoir at the headwaters of the Catawba at a site called Bridgewater and is installing 20,000 kilowatts in generating equipment there. It is also completing a new power development on the lower Catawba at a site called Wateree with 60,000 kilowatts capacity. The power available from these sources has been contracted for, part of it going to the Carolina Power & Light Co., which is building an additional interconnecting line from its system in South Carolina to Wateree station. During 1918 for a short time there was a shortage of power on this system due to unusual drought and the longer hours' use of power by industries, which would have been prevented had the storage reservoir been completed and in operation.

76. During a year of average river flow and allowing a reasonable reserve capacity and including the storage reservoir, the prime generating capacity of this system is 850,000,000 kilowatt hours annually, which is equivalent to a maximum load of 175,000 kilowatts at 55 per cent annual load factor, or over 200,000 kilowatts at a lower load factor. In average years this prime power will require 80,000,000 kilowatt hours of steam.

NOTE.—During 1917 the system generated 381,500,000 kilowatt hours by hydro plants and 80,100,000 kilowatt hours by steam. During 1918 the systems generated 424,579,800 kilowatt hours by hydro plants and 62,770,300 kilowatt hours by steam plants.

77. *Carolina Power & Light Co.*—This company with an interconnected system operated generating plants as follows:

	Kilowatts.
Blewett Falls, water power, installed capacity.....	30, 000
Buck Horn Falls, water power, installed capacity.....	2, 900
Raleigh, steam plant, effective installed capacity.....	3, 000
Goldsboro, steam plant, effective installed capacity.....	1, 000
	<hr/> 36, 900

78. These plants are connected by and operated in conjunction with a transmission system of approximately 155 miles of 100,000-volt line and 210 miles of 66,000-volt line. The system interconnects with that of the Southern Power Co. near Raleigh, as previously outlined, and power is transferred from one system to the other when facilities permit.

79. The company also operates a disconnected smaller system at Florence, Darlington, and Marion, S. C., with steam generated power and has under construction a line to connect with the Wateree station of the Southern Power Co. for the future supply of this system. A connection between the larger system at Raleigh and this system will ultimately be made which will provide interconnection with the Southern Power Co. at two points.

80. The prime generating capacity of the systems (exclusive of Florence, Marion, and Darlington) is 130,000,000 kilowatt hours annually, which is equivalent to a peak load of 27,000 kilowatts at 55 per cent annual load factor.

NOTE.—In 1917 the company actually generated 82,100,000 kilowatt hours of hydro power and 3,600,000 kilowatt hours of steam power. In 1918 the company actually generated 89,278,500 kilowatt hours of hydro power and 1,831,000 kilowatt hours of steam power.

PART 2.

ADDITIONS AND IMPROVEMENTS IN PROCESS OF BEING BUILT OR ADVISABLE FOR 1919 OPERATION.

STATE OF ALABAMA.

81. The Government is building a 60,000-kilowatt steam plant at Sheffield, Ala., which is scheduled for completion in April of this year, and has installed in the Warrior steam plant of the Alabama Power Co. a 30,000-kilowatt generator, which was completed and ready for operation on the first of this year. These plants are connected by a 30,000-kilowatt capacity single circuit 110,000-volt transmission line, and were primarily designed for service in connection with the Government nitrate plant at Sheffield.

82. It is recommended that these new power facilities be operated in conjunction with the system of the Alabama Power Co. for economy and reliability of power supply to industries in the State of Alabama as served from the lines of the Alabama Power Co. and for such service as may be required by Government or privately owned plants for nitrate or other electrochemical productions at Muscle Shoals. The economic relation of these power plants to a more comprehensive power scheme to include the other Southern States is outlined in part 3 of this report.

STATE OF GEORGIA.

83. In the State of Georgia there is a serious shortage of central station power to serve the present established and going industries.

84. During the summer season of 1918, when many of the factories were heavily engaged in war material production, there was a shortage which for a few weeks necessitated reducing the supply to nearly every industry in the State and absolutely shutting off the supply to some industries. Furthermore, there are many factories and other power users who were operating isolated steam plants at a very high cost for coal, where an expansion of the hydroelectric systems would conserve coal and reduce the cost of power.

85. The Georgia Railway & Power Co. are constructing a reservoir at Burton on the Tallulah River which is scheduled for completion in July of this year. This reservoir is to have an available storage capacity of 5,000,000,000 cubic feet and if it had been in service during 1918 it would have practically eliminated the shortage of power for war work on the Georgia Railway & Power Co. systems and reduced that on the connected systems. It is also adding a sixth unit to the Tallulah Falls plant, which will increase its installed capacity to a total of 72,000 kilowatts.

86. Also the Georgia Railway & Power Co. projected and started work and ordered equipment for a 48,000-kilowatt hydroelectric plant

on the Tugaloo River, but they have suspended work on this project and the order for machinery for the same, because they are unable to finance the construction, the cost of which is estimated at about \$3,500,000.

87. Appendix 8, herewith, gives a partial statement of the amount of power that is now being generated by isolated steam plants within reach of the transmission lines of the central station systems of Georgia which should, as a matter of economy and coal conservation, be generated by hydroelectric central station systems. This appendix enumerates an aggregate at 5,715 kilowatts with annual requirements of 16,235,000 kilowatt hours seeking central station service and 3,050 kilowatts with annual requirements of 10,455,600 kilowatt hours for the most part now in isolated plants which is quite likely to use central station connections, also 30,800 kilowatt capacity in steam plants now building or proposing to build in Georgia during this year.

88. At present four systems interconnect with the transmission lines of the Georgia Railway & Power Co. for the purpose of exchange of power between systems. These interconnecting lines are inadequate to meet the needs of the service. In most cases they are simply connections between distribution circuits. The company is preparing to increase the voltage of the connecting line to the Tennessee Power Co. in order to be able to transfer a larger amount of power.

89. It is recommended that an additional generating unit of 6,250 kilo volt-ampere capacity be added to the present Goat Rock plant of the Columbus Power Co. This unit will replace a large amount of steam generated power. The head gates, draft tubes, foundations, and a portion of the penstock are now in place for three such additional units.

STATES OF NORTH AND SOUTH CAROLINA.

90. The Southern Power Co. is adding to its generating plant capacity by the construction of a new hydro plant on the Catawba River at Wateree with an intallation of 60,000 kilowatts, which will be ready for operation the early part of 1919. It is also constructing a large storage reservoir on the headwaters of the Catawba River, which will be completed early in 1919, and which will provide the company with a means of equalizing the low flow of the river.

91. The company has already contracted to sell the output of Wateree station as soon as completed, and has been carrying some of this load on its steam reserve plants. The addition of the storage reservoir and the freeing of the reserve steam plants will enable the company to carry its load through a period of extreme drought, such as was experienced in the fall of 1918, without curtailment.

PART 3.

RECOMMENDED DEVELOPMENTS FOR FUTURE POWER SUPPLY AND INTERCONNECTION OF POWER SYSTEMS.

92. It is anticipated that in about five years the demand on the central systems of the States of Georgia, Alabama, Tennessee, North Carolina, and South Carolina, exclusive of the Aluminum Co.'s load and of the nitrate plant load at Muscle Shoals, will be 1,000,000,000 kilowatt hours more annually than at present and a progressive construction program should be carried out to provide for this increase in approximately five years.

93. The approximate distribution of this increased demand by States is estimated as follows:

	Kilowatt hours.
Alabama-----	350, 000, 000
Georgia-----	200, 000, 000
Tennessee ¹ -----	150, 000, 000
North Carolina and South Carolina-----	300, 000, 000
	<hr/> 1, 000, 000, 000

94. The recommendations for additional power construction to meet this demand will be treated below by States for individual State requirements, and a separate recommendation will be made for additional lines to constitute an interconnection between the State systems in order to afford a means for utilizing the diversity between the State requirements for exchange and equalization between sources of steam and hydro power in the respective States, and a means for interstate transmission from points of most efficient generation.

95. In preparing figures for additional power, consideration was given to the conditions under which the power would be used, which we have estimated for the industries of the Southern States, at an average production of 4,800 hours per year per kilowatt of maximum load (55 per cent annual load factor). (See Appendix 1.)

STATE OF ALABAMA.

96. To determine upon a plan for increasing the power system capacity in Alabama, preliminary studies were made of the available natural resources for power generation, and tentative figures were compiled for the construction and operating costs of power developments as follows:

The Coosa River for unregulated flow of river powers, in conjunction with steam plants.

The Coosa River powers regulated by Etowah storage.

¹ This is based on a reduction in the electrochemical load for aluminum manufacture heretofore supplied by the Tennessee Power Co.

The development of Little River power.

The direct generation by supersteam power plants located at coal mines.

The development of the Tallapoosa River with a large storage reservoir at Cherokee Bluff.

97. *Tallapoosa River development.*—As a result of the preliminary examinations, it was decided that the development of the Tallapoosa River, in conjunction with the present system of the Alabama Power Co. described in Part 1 under Alabama, will afford the most practical plan in Alabama for securing a large increase in power production. Furthermore, this development can be advantageously used in combination with the Muscle Shoals water power when completed. The following figures show approximately the results that would be secured by developing the Tallapoosa River in conjunction with the present Alabama Power Co. system. This combination will later be considered in conjunction with Muscle Shoals power and with the power systems of the other Southern States.

98. The reliable prime power capacity of the existing Alabama Power Co. system described in Part 1, under State of Alabama, is 80,000 kilowatts capable of economically generating 385,000,000 kilowatt hours per year under the anticipated daily and annual variations of load.

NOTE.—The aggregate amount of power in Alabama served by central stations outside of the districts reached by the Alabama Power Co.'s distribution is relatively small. (See Appendix 4.)

99. For the best utilization of the Tallapoosa River, in conjunction with this system, the following generating plant construction and operating estimate has been prepared for new hydro plants on the Tallapoosa River, aggregating 150,000 kilowatts installed capacity, together with a reservoir capable of storing water sufficient to generate 270,000,000 kilowatt hours with a draft of 60 feet (64,000,000,000 cubic feet) on the reservoir.

NOTE.—The proposed reservoir dam location is at Cherokee Bluff at a site described by Maj. H. B. Ferguson, in House Document No. 253, Sixty-third Congress, first session, page 53.

100. The figures on the Tallapoosa River development as a source of power for the State's industries include (in addition to the cost of the storage reservoir and generating plants) the necessary main high-tension trunk lines and substations for the transmission of the Tallapoosa power to the principal main centers of distribution established by the Alabama Power Co. and already a part of their system.

Description:

Cherokee Bluff Dam, to give maximum elevation of pool level (U. S. Geological Survey datum).....	feet.....	490
Total head developed in three developments.....	do.....	245
Average effective operating head, allowing for draw down on pond.....	feet.....	230
Capacity of storage reservoir (for 50-ft. draft).....	cubic feet....	64, 000, 000, 000
Kilowatt hours available from storage (with 50-ft. draft).....	kilowatt hours.....	270, 000, 000
Generating capacity installed.....	kilowatts.....	150, 000
Kilowatt hours produced in average year.....	kilowatt hours....	540, 000, 000

NOTE.—Based on stream flow at Sturtevant, Ala. (drainage area 2,500 square miles), plus 525 square miles between Sturtevant and Cherokee Bluff. See United States Geological Survey Water Supply Paper and United States Geological Survey Quadrangles. Correction for evaporation made by deducting

area of reservoir of 70 square miles. Drainage area 8,025 square miles less 70 square miles equals 2,955 square miles.

Cost:

Estimated cost of hydroelectric development including overflowed lands (three developments)-----	\$19,030,000
Estimated cost of transmission lines and right of way-----	3,328,000
Estimated cost of substations-----	1,386,000
	<hr/>
	23,742,000
Additional installation at Lock 12:	
Estimated cost of installing sixth unit at Lock 12-----	375,000
Estimated cost of equalizing dam below Lock 12 to regulate flow for navigation-----	119,000
	<hr/>
Total cost-----	24,236,000

NOTE.—The estimated costs given above include an allowance of 10 per cent to cover the interest during construction and the period of loading the plant.

101. *Generating capacity.*—The combination of the present Alabama Power Co. system (including the new Government 30,000-kilowatt generator recently installed at the Warrior steam plant) together with the proposed Tallapoosa 150,000-kilowatt development will have an operating capacity of 230,000 kilowatts, capable of generating 1,110,000,000 kilowatt hours annually under the anticipated conditions of service, or an increase of 725,000,000 kilowatt hours over the annual capacity of the present Alabama Power Co. system, and will be capable of producing this prime power in years of minimum river flow.

102. To produce 1,110,000,000 kilowatt hours in a year of normal or average river flow in the Coosa and Tallapoosa Rivers, the coal consumption in the steam plants of the proposed systems would be 210,000 tons annually, based on a coal consumption of 2.10 pounds of coal per kilowatt hour.

103. From this amount of power must be deducted the amount of power generated by water by the Montgomery Light & Water Power Co. and the Tallassee Mills, whose existing plants would be supplanted by the proposed Tallapoosa development. This amounts to 29,800,000 kilowatt hours annually. (See pt. 1, Montgomery Light & Water Power Co. and Tallassee Falls Manufacturing Co.) The net increase for distribution in the industrial centers equals 695,200,000 kilowatt hours annually.

NOTE.—In seasons of normal river flow it is estimated that the generation of power aggregating 1,110,000,000 kilowatt hours annually will be produced, as follows:

By the present Lock 12, Coosa River, hydro plant and Jackson Shoals plant, 370,000,000 kilowatt hours.

By the proposed Tallapoosa development, 540,000,000.

By the steam plants of the Alabama Power Co. system, 200,000,000 kilowatt hours.

Total, annually, 1,110,000,000 kilowatt hours.

104. *Cost of operation and maintenance of the proposed new plants.*—In the figures below no statistics are compiled or estimates made of the operating and maintenance cost of the Alabama Power Co.'s present system. The cost of power to be generated by the new facilities of the proposed Tallapoosa development, when combined with the present system, includes only the annual operating and maintenance cost of the new hydro plants and main transmission

lines to deliver the power to the substation centers of the present system, plus the cost of the additional coal required in the steam plants to supplement this power. The additional coal is figured as the difference between the amount required to supplement the full capacity of the present system (the production of 385,000,000 kilowatt hours yearly), 115,000 tons, and that required to supplement the combination of the present system and the new developments 1,110,000,000 kilowatt hours, 210,000 tons, or an increase of 95,000 tons.

105. As stated above, the net increase in power production from the Tallapoosa developments combined with the present system as compared with the full-load capacity of the present system alone is 695,200,000 kilowatt hours annually. The cost of operating these new hydro stations and transmission lines is estimated at \$216,000 annually. (See Appendix 1.) This amount of power will require additional coal consumption, as outlined above, of 95,000 tons.

15,000 tons at Gadsden, at \$3.10.....	\$46,500. 00
80,000 tons at Warrior, at \$2.18.....	170,400. 00
Annually (see Appendix G).....	216,900. 00

Taking the charges to capital, depreciation, obsolescence, and taxes at 10 per cent annually, this charge on the capital cost of \$24,236,000 will be \$2,423,600 annually. The sum of these costs \$2,856,500 representing the cost of producing and delivering the power to the industrial centers, is equivalent to 0.411 cents per kilowatt hour of energy available for distribution.

STATE OF GEORGIA.

106. In order to arrive at the most practical and economical means of producing electric power in excess of the present generating capacity of the existing central power systems of this State, careful analysis has been made of various natural resources for power generation. The figures have been prepared on the basis of an annual load factor of 55 per cent. (See Appendix 1.)

NOTE.—The annual load factor on the system of the Georgia Railway & Power Co. was 39.7 per cent in 1917 and 41.1 per cent in 1918, but when operated as proposed in conjunction with the large power systems of adjacent States the diversity of the loads and the increase of connected service will raise the load factor to 55 per cent.

107. The individual generating capacities of the major power systems in kilowatt hours per year of prime power are when operated as individual systems without interchange of power, in a year of average river flow and including steam plant operation, as follows:

	Hydro.	Steam.	Total prime power.
Georgia Railway & Power Co. (with Burton Reservoir completed).....	250,000,000	25,000,000	275,000,000
Columbus Power Co.....	110,000,000	10,000,000	120,000,000
Central Georgia Power Co.....	88,500,000	6,500,000	95,000,000
Total kilowatt hours per year.....	448,500,000	41,500,000	490,000,000

108. If these systems were combined and operated as one system, with sufficient transmission-line capacity for interchange of power, in a year of average river flow the combination would be capable of generating annually without steam-plant operation 500,000,000 kilowatt hours of prime power.

109. In a year of minimum recorded river flow the prime generating capacity of the combined systems would be 500,000,000 kilowatt hours, of which 112,000,000 kilowatt hours would be produced by steam.

NOTE.—The figures for power from the combined systems for the driest year are based on the run-off of 12 months ending September 30, 1914 (which for the rivers in Georgia was lower than for 1904). The figures are based on starting the year with water for 50,000,000 kilowatt hours stored in the Burton and Mathis Reservoirs, which have a combined capacity when full equivalent to 70,000,000 kilowatt hours. During such a year the total draft on the storage reservoirs would be equivalent to 46,000,000 kilowatt hours and the water caught in storage equivalent to 16,000,000 kilowatt hours, leaving stored water for 20,000,000 kilowatt hours in the reservoirs at the end of the year, which would be the lowest stage of the storage during the year. The steam plants having a combined capacity of 22,000 kilowatts would produce 112,000,000 during this driest year. During an average year with the above production of prime power there would be available from 40,000,000 to 70,000,000 kilowatt hours six months power.

110. It is recommended that for the best utilization of the existing systems of the State of Georgia, as outlined above, and for improved reliability of service, the major systems of Georgia should be interconnected with high-tension transmission lines of ample capacity for exchange of power between the various systems and the plants thereof, and should be operated for the most economical utilization of the existing power plants without consideration of individual ownership whereby in a year of average river flow the total generating capacity of the systems would be increased as above shown by 40,000,000 kilowatt hours over their capacity when operated as individual systems; and the generation by steam would be reduced in an average year from 41,500,000 kilowatt hours (requiring 58,000 tons of coal) to no steam operation.

111. In addition to the increased power available from a complete interconnection and joint operation of the present systems, and in order to provide for an increase of 200,000,000 kilowatt hours of estimated new load on a State-wide power system, preliminary studies were made of the available natural opportunities for power generation, and tentative figures were compiled for the construction and operating costs of power developments, as follows:

The Tallulah River below Mathis Reservoir.

The Chattahoochee River at Bartletts Ferry and at other points.

The Tugaloo River at Tugaloo, 2 miles below Tallulah Falls, and at Ralston, 7 miles below Tallulah Falls.

The Chattooga River, with four power sites and storage reservoir.

The Savannah River at Calhoun Falls.

The Flint River.

112. From present knowledge of the developments it appears that the best economy for increased power supply can be secured from the Mathis, Tugaloo, the Ralston, or the Bartletts Ferry developments, and in combination with all the existing systems, and it was decided to figure on these four proposed powers as affording the most

practical plan for securing a large increase in power for the State. The following figures show approximately the results that would be secured by these developments in combination with the present Georgia systems. This combination will later be considered in conjunction with Muscle Shoals power, and with the power systems of the other Southern States.

113. *Proposed Chattahoochee, Tallulah, and Tugaloo River developments.*—The plants of the major power systems of the State of Georgia are Georgia Railway & Power Co., the Central Georgia Power Co., and the Columbus Power Co. They have an aggregate installed capacity of 117,750 kilowatts in hydro plants and 21,500 kilowatts in steam plants, as previously described, and are capable of economically generating 500,000,000 kilowatt hours of prime power annually, which is equivalent to a system load of 104,000 kilowatts at 55 per cent annual load factor. (See Appendix 1.)

114. For increasing the power in the State by 185,000,000 kilowatt hours annually, a favorable development would be the proposed Mathis and Tugaloo power sites of the Georgia Railway & Power Co. For increasing the power in the State by 285,000,000 kilowatt hours of prime power annually, a favorable development would be the proposed Mathis, Tugaloo, and Ralston power sites of the same company. The Bartletts Ferry development of the Columbus Power Co. would furnish an annual increase of 175,000,000 kilowatt hours.

115. The following statement gives approximate data on the proposed installed capacity of these developments, the prime annual output, and the cost:

Elevation of dam crests (U. S. Geological Survey datum).

	Feet.
Mathis.....	1,689
Tugaloo.....	890
Ralston.....	745
Bartlett Ferry.....	519

Total head developed.

	Feet.
Mathis (maximum, 189 feet; minimum, 100 feet); average.....	175
Tugaloo.....	135
Ralston.....	100
Bartlett Ferry.....	110

Capacity of reservoirs (within available draw-down for use with above plants).

	Cubic feet.
Mathis.....	1,370,000,000
Burton (under construction).....	5,000,000,000

Generating capacity to be installed.

	Kilowatts.
Mathis.....	12,000
Tugaloo.....	48,000
Ralston.....	40,000
Bartlett Ferry.....	36,000
	<hr/> 136,000

Kilowatt hours produced in average year.

	Kilowatt hours.
Mathis.....	60,000,000
Tugaloo.....	125,000,000
Ralston.....	100,000,000
Bartlett Ferry.....	175,000,000
	<hr/>
	460,000,000

(Estimated with use of Burton and Mathis storage reservoirs combined with flow of Tallulah, Chattooga, and Chattahoochee Rivers.)

Cost.

Estimated cost of hydroelectric developments, including overflowed lands:

Mathis.....	\$1,650,000
Tugaloo.....	3,850,000
Ralston.....	4,070,000
Bartlett Ferry.....	4,000,000

These costs do not include transmission lines or substations, but do include step-up transformers at generating stations. For unit costs of transmission lines and substations see Appendix 6.

116. The "kilowatt hours produced in average year," as noted above, express the additional prime capacity which may be obtained by the individual developments, respectively. Furthermore, they are hydro power capacity, and in a year of average stream flow and if operated jointly in a combined system, as recommended above, no steam power would be required.

STATE OF TENNESSEE.

117. For the past three years approximately half of the output of the power system of the Tennessee Power Co. has been taken by the Aluminum Co. of America for the electrolytic production of aluminum. The latter company is now building hydroelectric developments in Tennessee and North Carolina, and looks forward to furnishing its own power needs. This action will release some 200,000,000 kilowatt hours annually, which will be available for supplying future demands on the power company system. It is anticipated that a large portion of this surplus will be taken by new industries in the near future. In addition to this, there are several new developments which have been studied whose construction is recommended, should further additional power be required. They are:

No. 3 development on the Ocoee River:

Operating head.....	feet.....	260
Installed capacity.....	kilowatts.....	15,000
Estimated cost.....		\$4,000,000

No. 4 development on the Ocoee River:

Morgantown reservoir storage capacity.....	acre-feet.....	80,000
Or when used through Nos. 1, 2, and 3 power plants with an aggregate head of 620 feet.....	kilowatt hours.....	37,000,000
Estimated cost.....		\$1,155,000

A second unit in the Great Falls plant:

Capacity of unit.....	kilowatts.....	9,375
Estimated cost.....		\$685,000

118. The construction of the above additions and their joint operation with the existing system of the Tennessee Power Co. will

increase the generating capacity of the system to 460,000,000 kilowatt hours per annum, and on the basis of a 55 per cent load factor the peak capacity will be raised to 95,000 kilowatts. In a year of average river flow no steam-generated power will be required.

SUMMARY AND RECOMMENDATIONS.

119. The following is a general summary of the preceding studies and a recommendation for the interconnection of all the power systems of the Southern States and for their joint operation, and a further recommendation for additional hydroelectrical developments to make possible the conversion of isolated plant service to central station systems and to provide for the power requirements of growing industries.

PRESENT ALABAMA SYSTEM.

120. The prime generating capacity of the present Alabama system in kilowatt hours per annum is as follows:

		Kilowatt hours
(a) In an average year:		
Hydro power	-----	275, 000, 000
Steam power	-----	110, 000, 000
Total power	-----	<u>385, 000, 000</u>
(b) In an extremely dry year:		
Hydro power	-----	242, 000, 000
Steam power	-----	143, 000, 000
Total power	-----	<u>385, 000, 000</u>

PRESENT GEORGIA SYSTEM.

121. Assuming that the present three major systems in the State of Georgia are interconnected and operated as one system, the combined system will have the following generating capacities in kilowatt hours per annum:

		Kilowatt hours
(a) In an average year:		
Hydro power	-----	500, 000, 000
(b) In an extreme dry year:		
Hydro power	-----	370, 000, 000
Steam power	-----	130, 000, 000
Total power	-----	<u>500, 000, 000</u>

PRESENT TENNESSEE SYSTEM.

122. The present Tennessee system will have a prime generating capacity limited by the present steam equipment when used to maintain this prime capacity in an extreme dry year.

		Kilowatt hours
(a) In an average year:		
Hydro power	-----	373, 000, 000
Steam power	-----	12, 000, 000
Total power	-----	<u>385, 000, 000</u>
(b) In an extreme dry year:		
Hydro power	-----	345, 000, 000
Steam power	-----	40, 000, 000
Total power	-----	<u>385, 000, 000</u>

PROPOSED PLAN FOR INTERCONNECTING THE MAJOR POWER SYSTEMS FOR JOINT OPERATION.

123. It is recommended that an interconnection be made between Georgia and Alabama by a single circuit 110,000-volt line from Anniston, Ala., to Cedartown, Ga., 55 miles, with voltage and phase regulating apparatus at both of the above points, and by a single circuit 110,000-volt line from Lock 12 on the Coosa River in Alabama via Cherokee Bluff to West Point, Ga., 90 miles, with voltage and phase regulating apparatus at West Point. Approximate cost of the connections will be \$2,130,000.

124. To make a connection between the Tennessee and Georgia systems a single circuit line (with voltage and phase regulating apparatus) will be required between Cedartown, Ga., and the Cleveland switching station of the Tennessee Power Co. in Tennessee, a distance of 140 miles. The approximate cost of the interconnection will be \$1,920,000.

125. The operating capacity of the present systems combined as above in kilowatt hours per year will be as follows:

(a) In an average year:	Kilowatt hours.
Hydro power-----	1,238,000,000
Steam power-----	132,000,000
Total power-----	1,370,000,000
(b) In an extreme dry year:	
Hydro power-----	1,040,000,000
Steam power-----	330,000,000
Total power-----	1,370,000,000

Recommended new developments.—To meet the future power requirements of the growing industries of these three States and to convert isolated power plants to central-station service there are a number of undeveloped water-power resources which may be used. These are given below; their capacities when operating in conjunction with the present systems are given in kilowatt hours per year.

126. Combined capacity, including Tallapoosa:

In an average year—	Kilowatt hours.
Hydro power-----	1,948,000,000
Steam power-----	154,000,000
Total power-----	2,100,000,000
In a dry year—	
Hydro power-----	1,490,000,000
Steam power-----	610,000,000
Total power-----	2,100,000,000

The total increase from Tallapoosa development (695,200,000 kilowatt hours) will cost \$0.0046 per kilowatt hour, including fixed charges, taxes, and operation.

NOTE.—695,200,000 kilowatt hours annual increase from Tallapoosa, as above, is less by 15,000,000 kilowatt hours than the anticipated increase in central-station service for the three States during the next five to seven years, as previously discussed (par. 9, etc.).

NOTE.—The estimates of cost for generation and high-tension transmissions do not include distributing expenses. They only provide for the delivery of power at the main substation bus bars, corresponding in point of delivery to the bus bars of steam or other generating plants located in industrial centers from which distribution is carried. Neither is allowance made for energy lost in distribution.

127. Looking further to the future than five to seven years, or in case large electro-chemical or other unforeseen uses call for further extension of the interstate power systems, other power resources are available for development to add to the capacity and further increase the central power resources of the three States.

NOTE.—It is noted that while Tallapoosa development is set out above as the logical first step for increasing power of an interconnected system for three States, expediency may determine that Tallapoosa development may not be the first development accomplished.

128. The logical sequence of further developments following Cherokee or Tallapoosa as above, would depend upon the use to be made of the Muscle Shoals plant on the Tennessee River now being built by the Government. If the Muscle Shoals power is not to be distributed in the industrial power sections of the States, the next logical development would be the Bartlett Ferry development on the Chattahoochee River in Georgia. The Bartlett Ferry site may be developed for an installation of 36,000 kilowatts. This development when interoperated with the systems of the three States would make possible the following generating capacity:

In an average year (Tallapoosa and Bartlett Ferry included):		Kilowatt hours.
Hydro power	-----	2, 120, 000, 000
Steam power	-----	110, 000, 000
Total power	-----	2, 230, 000, 000

129. Following this, if still further development is required, the next development in order would be the Mathis-Tallulah development on the Tallulah River, Ga., between the Mathis Reservoir and Tallulah Lake, and the Tugaloo development on the Tugaloo River, Ga., immediately below the confluence of the Chattooga River. The generating capacity of the entire system with these developments in service would be:

In an average year:		Kilowatt hours.
Hydro power	-----	2, 336, 000, 000
Steam power	-----	164, 000, 000
Total power	-----	2, 500, 000, 000

PART 4.

ADVANTAGES OF CENTRAL SYSTEMS AND THEIR INTER-CONNECTION AND EFFECT OF INTEREST CHARGES ON COST OF POWER.

130. Under the existing conditions of power generation, particularly in the industrial and populous districts, there is a serious waste of resources and a heavy expense for labor and materials for power production that can be and should be eliminated by further centralization of power generation, by unifying the operation of existing central electric systems, and by discontinuing power production in isolated steam plants. The States under consideration have splendid water-power resources which are only partly developed, and even the developments already made are not sufficiently interconnected and are not operated for the best interchange of facilities to secure the highest economy and reliability of service. The results in economy and reliability secured by existing hydro plants in these States are favorable as compared with power generated in isolated steam plants, and they afford a firm foundation of experience that demonstrates the economy and reliability of hydro power supplemented where necessary by large and efficient central steam plants favorably located for coal and condensing water.

131. The major central station systems of the three States in question are furnishing 1,220,000 kilowatt hours annually. Our investigation shows, however, that in the districts occupied by the central systems of these States there are millions of kilowatt hours produced annually by relatively small and inefficient steam plants; that numerous new isolated steam plants are being built or are proposed for industrial work. A satisfactory central station service to dispense with the present isolated plants and to provide for anticipated increased needs during five to seven years should now be started or arranged for. This will require an increased annual production by central stations of a billion kilowatt hours, which, if provided by hydroelectric plants instead of isolated steam plants, will save a large amount of coal annually. Proper interconnection and joint operation of the central station systems themselves would make a further annual saving of thousands of tons of coal as compared with the present central station methods.

132. The general plan for interstate power service described in this report is devised with the purpose of producing the requisite power at the lowest obtainable capital and operating cost commensurate with the highest degree of service reliability.

133. In the existing going power companies, with their central generating plants and transmission line systems and regulating reservoirs on the rivers as a foundation for future construction, further expenditures should secure proportionately larger returns in power produced than expenditures heretofore made. Furthermore,

the work already done has demonstrated the practical economy of water powers in the Southern States so that the hazard of new investments in work of this character should be small and the necessary capital should not cost as much in interest charges as capital heretofore secured. To obtain cheap power from water powers this is of first importance, since the operating cost of hydro plants is small, and the principal cost of hydro power is the fixed charges on the investment.

134. We note that two things, entirely within the control of the bodies politic under which power companies operate, are working against low rates for power supplied by public service electric companies from central systems.

135. First, the high rate of interest paid by public service electric companies on money invested in their business reacts necessarily in the price of power. High interest rates result largely from uncertainty regarding the earnings that electric companies will make depending on the rates that will be allowed by public service commissions, municipalities, or other regulatory bodies. If investors were practically assured of a definite return, even though a modest one, on their money invested in well designed and operated power properties, power companies would be able to obtain capital at much less cost than under present conditions where political commissions, that are frequently subject to change and are often inexperienced, regulate prices.

136. Certain States, which have established and announced what they consider a fair rate of return on public utility investments, have thereby, by direct announcement or otherwise, substantially guaranteed the earnings of utility companies, a procedure that must encourage utility investments in such States and reduce interest rates, and thereby cheapen the cost of service.

137. Second, the high cost of money that results from the uncertainty regarding the earnings on capital invested in electrical power properties curtails the construction of these properties, and consequently delays the adoption of central station power to supplant isolated power plants and at the same time retards the construction of central station plants of larger sizes and the corresponding superior economy in power generation.

138. These two conditions in the power business, namely, the high cost of money and the restricted size of generating plants, work together to increase the cost of power and place an unnecessary burden on industries.

ADVANTAGES TO BE OBTAINED FROM INTERCONNECTION OF THE LARGE EXISTING POWER SYSTEMS AND THE FUTURE POWER DEVELOPMENTS.

139. The advantages of the interconnection of large power systems, which are in themselves self-contained and whose generating plants are already interconnected by tie and distribution lines for independent economical operation, have been partially brought out in Part Three. Though actual figures of the amount of power possible of transfer over a proposed interconnection may not in themselves justify the interconnection of State systems, there are other addi-

tional facts that point to the advisability of such interconnections. Such are—

- (1) The increased reliability of operation;
- (2) The reduction of the total reserve capacity required for an interconnected system over the aggregate amount required in separately operated systems; and, further, the better utilization of that reserve capacity;
- (3) The advantage arising from the diversity of loads existing in a larger system;
- (4) A diversity also in the natural stream flow between the drainage areas, both during the seasons of any one year and during longer periods of a year or more, it has been found that the flow in one stream is above its own average flow, while during the same period the flow of another stream of an adjacent drainage area is below its average flow;
- (5) A reduction in the amount of steam power required for an interconnected system over the aggregate amount of steam power that would be required in separately operated systems; this is discussed elsewhere;
- (6) The maximum operation of the most efficient steam plants to supply any given amount of steam power required in the combined system from the viewpoint of economy and coal transportation;
- (7) The economy possible in plant construction whereby any newly constructed plant will be loaded up in shorter time, such new power plant additions will be built in successive steps instead of several plants, one for each separately operated system, being constructed simultaneously;
- (8) The possibility of a more judicious location of steam plants, such as at coal-producing centers and at points accessible to condensing water;
- (9) Secondary power in large lots made possible by the summation of small amounts of secondary power existing in the separately operated systems, but occurring simultaneously, which may be used for aluminum or other electrochemical processes; and
- (10) With reference to this particular interstate system, a very large system will be created which will serve in advance as a preparation for the distribution of the very large blocks of power which will be made available by the Muscle Shoals development until such time as the growth of additional market in the immediate vicinity of Muscle Shoals will take over its power.

PART 5.

GOVERNMENT HYDROELECTRIC DEVELOPMENT AT MUSCLE SHOALS, ALA.

RECOMMENDATIONS FOR ITS UTILIZATION.

140. The proposed hydro development at Muscle Shoals authorized by the Government and now being built under the direction of the Chief of Engineers, United States Army, provides for a high dam in the Tennessee River and the installation of electric machinery for the generation of power. The river flow and other natural conditions at the site selected will permit the generation of 60,000 kilowatts during stages of low water in an extreme low year, and 300,000 kilowatts can be generated during five months in years of normal river flow.

141. By act of Congress (39 Stat., 215) it is provided that "the plant or plants provided for under this act shall be constructed and operated solely by the Government and not in conjunction with any other industry or enterprise carried on by private capital." The terms of the act are such that it would be unlawful to interconnect this plant with central station power systems of the Southern States and use even a portion of this power for other than Government industries.

142. This report on the power resources of the Southern States has been prepared to point out the most economic and reliable source of power that can be utilized for serving the industries of the South with a view to securing maximum economy in generation, and the resources in water and steam power thus far considered have excluded the Muscle Shoals project, by reason of the existing law prohibiting the use of this power for private purposes.

143. The procedure is illogical and unreasonable, because in order to provide cheap power it is necessary that the best sources of power be used, whether they are hydroelectric developments using the natural flow of the rivers, or whether they are hydroelectric powers with storage reservoirs that conserve the water during high-water stages for use during low-water stages, or whether they are sources of steam power, and further it is necessary to operate these powers jointly to obtain maximum economy, reliability, and conservation of resources in fuel, labor, and materials.

144. The best economy and reliability can not be secured by any one development, whether it is hydropower by flow of stream, or by storage, or steam power, but will be obtained by a suitable combination of these different sources and by the interconnection of the systems supplied by them. Muscle Shoals has been selected by the Government as a favorable location for the production of cheap power. The proposed design will furnish 100,000 kilowatts of prime power

and 200,000 kilowatts of second-class power in an average year. The steam plant of 60,000 kilowatts which the Government has installed at Muscle Shoals is capable of converting a portion of the second-class power to prime power. But this combination with a steam plant at Muscle Shoals, regardless of whatever economy may result, can not be, broadly speaking, as favorable for all interests, either the Government interests or private interests, as a combination of the Muscle Shoals steam and hydro powers with an interconnected group of public-utility systems as described in this report. To segregate the Muscle Shoals power facilities from the other systems of the country is contrary to the policy recommended and strongly advocated, that is, of interconnecting all of the efficient going power systems and jointly operating them for maximum economy. The same principle which works for increased economy by interconnecting the public-utility power systems of the Southern States applies to a further interconnection including the Muscle Shoals plants, and in the interest of cheap and reliable power the law should be changed and the interconnection and joint operation of all of the developed powers should be provided for.

145. It is important that the law should be modified and the plans perfected at an early date for the joint operation of all of the southern electric utilities and the Muscle Shoals power, since the recommended future construction for development of power facilities for the Southern States must depend, in a large measure, on whether or not Muscle Shoals will be available for other than Government work. For instance, if Muscle Shoals power is to constitute an important source of the generating capacity of an interconnected system for the Southern States, the logical procedure for other developments by the public-utility companies will be to build hydro plants with large storage reservoirs and steam plants, both of which will work economically in conjunction with the second-class power of Muscle Shoals, instead of developing additional flow of stream hydro power, which they might otherwise do if Muscle Shoals will not eventually be available for interconnection; and, on the other hand, if they develop flow of stream power, instead of storage hydro or steam power, for lack of assurance that Muscle Shoals will not be available in a few years, their own resources will not be of a nature to advantageously supplement Muscle Shoals and turn its second-class power into prime power should the Government policy later be changed. Even if a Government demand is built up for the entire use of Muscle Shoals, the Government would be handicapped in having a large amount of second-class power, which is not as valuable as prime power, and for which it would not have the most effective source for conversion of second class to prime power.

146. It is especially desirable that the interconnection to the combined southern power system be available for the purpose of distributing the Muscle Shoals power immediately upon its completion, and at least until its own market can be obtained, and that the developments for the next 5 to 10 years be directed toward the construction of such plants as will advantageously supplement Muscle Shoals. By this is meant that by the time Muscle Shoals is completed it is perfectly practicable for the power systems of the Southern States to acquire a connected load that will absorb a large part of the Muscle

Shoals output and to have installed such plants of their own creation as will be useful to turn Muscle Shoals second-class power into prime power.

147. It is argued that the Government steam plant can be used, when the hydro plant at Muscle Shoals is finished, to turn a large part of the second-class power into prime power. This is true; it can be used, but it is not the best plan available. There are large steam plants already built, and others will probably build before Muscle Shoals is completed, which, because of their more advantageous location for fuel, can make steam power more cheaply than the Government steam plant at Sheffield. Also, if the future load for Muscle Shoals is in a large part located at industrial centers in Alabama instead of in the Muscle Shoals-Sheffield district, the existing steam plants and prospective future steam plants will be more favorably located than the Muscle Shoals steam plant for joint operation with Muscle Shoals hydro power. This feature is important from standpoint of reliability of service and transmission cost as well as in economy of generation. In fact, if Muscle Shoals is interconnected with the other southern power systems and generally operated with them for maximum economy, the steam plants in the industrial sections of Alabama, and favorably located at the mines for cheap fuel, would be put into operation in case of low water before the Muscle Shoals steam plant would be started.

148. If interconnection between Muscle Shoals and the big public utility power companies of the Southern States is not planned for in the near future and eventually carried out under favorable conditions, the Government development at Muscle Shoals is liable to result, not in cheapening power for the industries of the South, but rather in increasing the cost. It is a matter of common knowledge that one of the large private interests acquired the water-power site at Muscle Shoals and spent a large sum of money in preparation for a hydro development similar to the one now being built by the Government, with the intention of distributing this power to the industries of Alabama, which would logically later on, through interconnections, be extended to service in Georgia and Tennessee. The Government has come into the situation and taken over this source of power and is building the plant, as provided by law, exclusively for Government use, and if this is carried out, it will result in private industries being deprived of this natural resource, which, by reason of the Government's own action in selecting this power for its use, may be regarded as a cheap source of power.

149. We have no figures as to what the Government estimates the cost of Muscle Shoals power will be, either primary power or second-class power, since the undertaking at this place is for the joint purpose of improving navigation and for creating power, and we are not informed as to the proportionate charge that goes to these two purposes. It is, however, obvious that if a big power load is to be built up about Muscle Shoals, it must be done either by direct Government operation or else the attraction in the way of low-priced power must be very marked to divert manufacturing from the present industrial centers and favorable locations for raw materials and transportation, to the district adjacent to Muscle Shoals, which is sparsely developed industrially. If the inducement in the way of

cheap power is sufficient to overcome the natural conditions as established by the superior industrial progress in other sections, the power at Muscle Shoals must be made available at a relatively low rate, which also, without the modification of the present law, would have to be wholly for Government purposes.

150. It therefore appears that a broad and well-founded judgment would dictate that the Muscle Shoals development should be interconnected for exchange of power with the existing power systems of the Southern States, and that this interconnection and exchange should be arranged for without delay, so that future construction, both at Muscle Shoals and elsewhere, can be directed for the production of plants which will supplement each other for economy of construction and operation.

APPENDIX E-1.

ANNUAL SYSTEM LOAD FACTORS OF THE SOUTHERN POWER SYSTEMS.

For the purpose of this report the capacity of and the operating costs of various proposed power plants in the Southern States are figured on a common basis of 4,800 kilowatt hours of annual production for each kilowatt of demand on the system at the time of maximum load during the year. The load factor of the major systems of the Southern States during past years varies through wide limits. The actual weighted average annual load factor of all the major systems for the year 1917 was 50.2 per cent. For the same year, the weighted average annual load factor of the power systems of Alabama, Georgia, and Tennessee was 59 per cent. The latter figure was raised by the power furnished to the Aluminum Co. by the Tennessee Power Co. and to the electric steel and to the metallurgical furnace loads at Anniston by the Alabama Power Co. It did not include any power delivered to the nitrate plant at Muscle Shoals. In preparing these weighted averages no allowance was made for diversity between peak loads on the various systems.

In preparing figures for additional future power supply and assuming an interconnected system consideration was given to the conditions under which the power would be delivered. For serving the combined industries of the Southern States we have estimated an average annual production of 4,800 hours per kilowatt of maximum system load during the year (55 per cent annual load factor). This is believed to be the output that will be required to meet the demands of industry fluctuating between daytime load and nighttime load and Sunday and week-day loads and for seasonal changes. The conclusion was arrived at after careful examination of the existing power-system loads and upon consideration of the nature of the industries to be served, including mills, public utilities, and electrometallurgical and other works, and upon a further consideration that all the major systems of the Southern States will be interconnected.

If the use of power were practically continuous throughout every hour of every 24 and throughout each day of the year, making a yearly load factor, approximately 80 per cent more or less, these calculations would be widely modified. Such conditions of nearly continuous use seldom occur except in electrochemical operations.

APPENDIX E-2.

PARTIAL LIST OF EXISTING AND PROPOSED STEAM PLANTS OF THE STATE OF GEORGIA.

1. *List of concerns willing to take power from Georgia Railway & Power Co. as soon as it is available, requiring no trunk-line extensions.*

Name.	Location.	Demand.	Yearly.	Present plant.
		<i>Kilowatts.</i>	<i>Kilowatt hours.</i>	
New Ice Co.	Carrollton	50	120,000	Steam.
Consumers Ice Co.	Gainesville	100	200,000	Do
Mandeville mills.	Whitesburg	75	100,000	None.
International Products Co.	Atlanta	75	145,000	Do.
Southern Railway shops	do.	300	800,000	Steam.
Lavonia cotton mills.	Lavonia	300	720,000	Do.
Towers & Sullivan	Rome	100	240,000	Do.
Fairbank Scale Co.	do.	100	240,000	Do.
City of Rome waterworks.	do.	250	1,500,000	Do.
Oglesby Granite Co.	Elberton	150	300,000	Do.
Royston oil mill.	Royston	100	250,000	Do.
Atlanta cotton mill.	Atlanta	125	600,000	None.
C. E. Galt cotton gin.	Kennesaw	40	20,000	Do.
City of Bowman	Bowman	50	50,000	Do.
W. & A. shops.	Atlanta	200	400,000	Steam.
		2,015	5,665,000	

2. List of present customers of Georgia Railway & Power Co. desiring more power.

Name.	Location.	Demand.	Yearly.	Present plant.
		<i>Kilowatts.</i>	<i>Kilowatt hours.</i>	
Standard mills.....	Cedartown.....	500	1,250,000	Steam.
Barrow Co. cotton mills.....	Winder.....	100	100,000	None.
Pratt Engine & Machinery Co.....	Atlanta.....	100	300,000	Steam.
United States Penitentiary.....	do.....	1,200	2,500,000	None.
American Machinery & Manufacturing Co.....	do.....	1,200	5,000,000	Do.
Mandeville mills.....	Carrollton.....	500	1,300,000	Steam.
Diamond Rubber Co.....	Atlanta.....	100	100,000	None.
		3,700	10,550,000	

3. List of prospective customers of Georgia Railway & Power Co. requiring very little sales work and no long trunk feeder extensions.

Name.	Location.	Demand.	Yearly.	Present plant.
		<i>Kilowatts.</i>	<i>Kilowatt hours.</i>	
City of Commerce.....	Commerce.....	150	800,000	Steam.
Harmony Grove Mills.....	do.....	1,000	2,000,000	Do.
Lawrenceville Manufacturing Co.....	Lawrenceville.....	250	600,000	Do.
Piedmont Cotton Mills.....	East Point.....	150	200,000	Do.
Echota Mills.....	Calhoun.....	300	1,000,000	Do.
Beverly Mills.....	Beverly.....	350	1,800,000	Do.
Carhart Mills.....	Elberton.....	350	1,600,000	Do.
City of Adairsville.....	Adairsville.....	75	120,000	None..
McNeil Marble Co.....	Marietta.....	150	360,000	Steam.
Acworth Cotton Manufacturing Co.....	Acworth.....	150	375,000	Do.
		3,050	10,455,000	

4. List of concerns installing steam plants in Georgia.

Name.	Location.	Capacity of steam plant.
		<i>Kilowatts.</i>
Bibb Manufacturing Co.....	Porterdale, Ga.....	3,000
Exposition Cotton Mills.....	Atlanta.....	3,000
		6,000

5. List of concerns figuring on installing steam plants in Georgia.

Name.	Location.	Capacity of steam plant.
		<i>Kilowatts.</i>
Mandeville Mills.....	Mandeville.....	500
West Point Manufacturing Co.....	West Point.....	5,000
Calloway Institute.....	La Grange.....	7,500
Crown Cotton Mills.....	Dalton.....	300
Hamilton Carhart Co.....	Atlanta.....	500
City of Thomasville.....	Thomasville.....	1,000
		14,800
Central Georgia Power Co. (steam auxiliary to hydroelectric system).	Macon, Ga.....	10,000
		24,800

APPENDIX E-3.

ESTIMATED DISTRIBUTION BY STATES OF THE FUTURE POWER REQUIREMENTS OF CENTRAL SYSTEMS.

[1,000,000,000 kilowatt hours of annual capacity.]

	Distribution of 1917 output.		Distribution of future billion on same basis.
	Kilowatt hours.	Per cent.	
Alabama.....	288,300,000	16.4	<i>Kilowatt hours.</i> 164,000,000
Georgia.....	379,177,000	21.6	215,000,000
Tennessee.....	547,900,000	31.1	311,000,000
North and South Carolina.....	547,300,000	31.0	310,000,000
	1,762,677,000	100.0	1,000,000,000

	Estimated additional 1918 requirements by systems of the States.		Distribution of future billion on same basis.
	Kilowatt hours.	Per cent.	
Alabama.....	146,800,000	39.2	<i>Kilowatt hours.</i> 392,000,000
Georgia.....	38,754,000	10.3	108,000,000
Tennessee (-).....	19,000,000	-----	-----
North and South Carolina.....	189,800,000	50.5	505,000,000
	375,354,000	100.0	1,000,000,000

Revised estimate of distribution of future billion kilowatt hours to be acquired in 5 years.

	Kilowatt hours.	Per cent.	Per cent increase annually on 1917 output.
Alabama.....	350,000,000	35.0	24.0
Georgia.....	200,000,000	20.0	10.5
Tennessee.....	150,000,000	15.0	15.5
North and South Carolina.....	300,000,000	30.0	11.1
	1,000,000,000	-----	-----

¹ Eliminating service to Aluminum Co. this increase is 9.6 per cent on remaining output.

APPENDIX E-4.

RELATIVE MAGNITUDE OF THE ANNUAL OUTPUT OF THE MAJOR POWER SYSTEMS COMPARED AS TO THE TOTAL CENTRAL STATION OUTPUT.

	Kilowatt hours generated in 1917.
Alabama:	
Alabama Power Co.....	288,300,000
Montgomery Light & Water Power Co.....	24,572,000
Montgomery Light & Traction Co.....	12,275,000
Mobile Light & Railroad Co.....	5,000,000
Mobile Electric Co.....	10,962,000
Total.....	341,109,000
Census report for all central stations of State.....	362,275,905
Proportion of companies above to total..... per cent.....	94.3

		Kilowatt hours generated in 1917.
Georgia:		
Georgia Railway & Power Co.	-----	286,400,000
Columbus Power Co.	-----	58,569,000
Central Georgia Power Co.	-----	59,147,000
Augusta-Aixon Railway & Electric Corp.	-----	38,916,125
Savannah Electric Co.	-----	80,783,790
Savannah Lighting Co.	-----	8,456,000
Total	-----	457,271,915
Census report for all central stations of State	-----	503,467,262
Proportion of companies above to total	----- per cent.	90.9
Tennessee:		
Tennessee Power Co.	-----	547,900,000
Census report for all central stations of State	-----	655,596,681
Proportion of companies above to total	----- per cent.	83.5

APPENDIX E-5.

FIXED CHARGES ENTERING INTO THE COST OF POWER.

In this report it is figured that the cost of power over and above operation and maintenance expenses will include an annual return on invested capital to cover interest, taxes, depreciation, and obsolescence, as follows:

A. On hydroelectric plants, including lands, dam, buildings, equipment, main high-tension transmission lines, and main high-tension substations, an annual charge of 10 per cent of the total capital cost. For the Tallapoosa development the fixed charges were figured as follows:

Item.	Estimated capital cost.	Per cent for fixed charges.			
		Interest.	Taxes.	Replace- ment reserve.	Total.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Lands.....	\$5,730,000	7.50	1.25	0.0	8.75
Dams and structures.....	8,600,000	7.50	1.25	0.75	9.50
Equipment.....	4,700,000	7.50	1.25	3.00	11.75
Transmission lines.....	3,336,000	7.50	1.25	2.00	10.75
Substations.....	1,386,000	7.50	1.25	4.00	12.75
	23,742,000	-----	-----	-----	¹ 10.13

¹ Average.

NOTE.—Ten per cent is considered generally sufficient for main steel-tower transmission lines, together with the connected high-tension substations. It would be insufficient for substations alone.

B. On steam turbine plants, complete, with land, buildings, and equipments, 11.75 per cent annually.

NOTE.—The above figures of 10 per cent on hydroelectric systems and 11.75 per cent on steam plants were adopted for figuring the cost of power after careful consideration of the relative permanence of the lands, structures, and equipment entering into the various parts of hydroelectric developments and steam turbine power plants.

They take into consideration the fact that the principal properties and structures in hydroelectric developments have a greater permanence of value than in steam turbine plants.

APPENDIX E-6.

COST OF CONSTRUCTION OF HIGH TENSION TRANSMISSION LINES AND SUBSTATIONS.

For estimating the cost of steel tower 110,000-volt transmission lines, including right of way in Alabama, a prewar cost of \$9,000 per mile for double-circuit 110,000-volt 2/0 B. & S. copper conductors was used. For future construction this prewar cost was advanced 40 per cent, making the cost of double-circuit lines \$12,600. For single-circuit lines on double-circuit towers deduct \$1,700 per mile for three 2/0 conductors and 1 mile of insulators, making the post-war cost of 110,000-volt single-circuit lines on double-circuit towers, complete with right of way, lightning protection, etc., \$10,900 per mile.

NOTE.—The Georgia Railway & Power Co.'s double-circuit, 110,000-volt lines with six conductors of 2/0 copper from Tallulah Falls to Atlanta cost \$8,125 per mile at before-the-war prices with 12-cent copper.

110,000-VOLT SUBSTATIONS.

Before the war 110,000-volt substations, complete, including land, transformers, outdoor switching apparatus, buildings, oil-drying outfits, etc., cost the Alabama Power Co. \$6 per kilo volt-ampere of installed capacity. For post-war cost estimates add 40 per cent to this prewar cost, which makes \$8.40 per kilo volt-ampere of installed capacity.

APPENDIX E-7.

ESTIMATED COST OF STEAM COAL FOR FUTURE OPERATIONS.

ALABAMA COAL.

Steam coal in Alabama sells exclusively by the short ton of 2,000 pounds.

For their Gadsden plant, prior to the war, the Alabama Power Co. paid \$1.20 per ton for washed coal, f. o. b. mines, and \$1.10 per ton for unwashed coal, and used about equal amounts of both grades. Both grades had approximately 13,500 B. t. u. per pound.

Before the war Gadsden coal came largely over the Southern Railroad from the Jasper, Parrish, Cordova, and Drifton group of mines. Some was shipped via the Louisville & Nashville Railroad from the Altoona, Shiras district, the price at the mines, however, being the same in both districts.

Some grades of Alabama slack sold as low as 80 cents to 90 cents per ton, f. o. b. mines, but the inferior quality overcame the advantage of low price.

Shortly prior to the armistice the better grades of coal were selling at the mines at the Government price of \$2.85 per ton, plus 15 cents per ton agents' commission, or \$3 per ton.

Freight rates on Alabama coal to Gadsden steam plant and to Sheffield, Ala., both prior to the war and at the present time, are shown in the following tabulation. The present time freight rates include 3 per cent war tax:

	Prior to June, 1918.	Present.
Freight to Gadsden on coal:		
Via Southern Ry.—		
Jasper and Parrish, Leespeer, Cordova, Drifton group.....	\$0.80	\$1.34
Via St. Louis and San Francisco—		
Dora group.....		1.24
Carbon Hill group.....		1.34
Via Louisville & Nashville—		
Altoona District, Shiras and all other mines on L. & N. in State of Alabama.....	.70	1.24
Freight to Sheffield on coal:		
Via Southern Ry.—		
Jasper and Parrish.....	.75	1.24
Leespeer, Cordova, Drifton group.....	.85	1.34
Via St. Louis-San Francisco—		
Dora group.....	1.20	1.55
Carbon Hill group.....	1.20	1.55

Figuring the future price of steam coal at the Alabama mines to cover a brief period of two to five years from the present time, the cost might be estimated at the prewar price of \$1.20 per ton for washed coal plus 40 per cent to cover the expected after-the-war increase in labor and material. This would make the price \$1.68, as compared with the prewar price of \$1.20.

NOTE.—This is the ratio used for increasing prewar construction costs to arrive at the probable postwar cost for construction within the next two to seven years.

In estimating the cost of coal for a longer period—say, 2 years up to 25 years after the war—a further addition should be made to coal-cost estimates

to allow for certain factors which may be expected to influence the future coal price, as follows:

A. Experience extending over the past 20 to 30 years shows there has been a tendency to a rising price for coal, irrespective of passing trade or war conditions.

B. Coal values in the ground and mining royalties are expected to have an upward tendency to higher values.

C. During succeeding years the best and most accessible coal veins will be worked out, necessitating production from less available sources.

Considering these facts and after consultation with large coal users it has been decided to base future estimates for the best Alabama steam coal on a price of \$1.75 per short ton at the mines.

Gadsden rate.—Freight rates from the mines in Alabama to Gadsden and Sheffield have been figured at the rates in effect at the beginning of 1919, which are 77 per cent to 92 per cent higher than prewar rates to Gadsden and 30 per cent to 65 per cent higher than prewar rates to Sheffield, as shown in the above table. Based on these figures, steam coal at Gadsden for future requirements extending over a period of years is figured at \$3.10 per ton. Before estimating coal prices at Sheffield other sources of coal than Alabama should be considered.

Warrior rate.—For the Alabama Power Co.'s Warrior steam plant a large amount of coal can be mined near the plant and delivered for a haulage charge not to exceed 10 cents per ton. The mines adjacent to Warrior plant do not have sufficient capacity to supply Warrior plant with a large amount of coal for a long period of years, and if coal for the operation of the Warrior station is obtained by rail from the near-by coal fields of Parrish or thereabouts, the freight charge at present rate would be 80 cents per ton. If half the coal were secured from the adjacent mines at 10 cents per ton and half from the Parrish coal field at 80 cents per ton freight, the average charge would be 45 cents per ton.

It appears that if coal mines along the Warrior River are later equipped with tipples for loading barges on the Warrior River direct from the mines, the Warrior plant should be able to secure coal from near-by fields by barge at a much lower freight rate than the present Government short-haul price of 80 cents per ton.

In view of this latter opportunity and other conditions mentioned, we have estimated the average transportation charge on coal for the Warrior steam plant for future requirements, including the coal mined adjacent to the power plant and coal secured from near-by fields by rail or water, to be 37½ cents per ton. This gives a price per ton, f. o. b. plant, of \$2.13.

GEORGIA COAL.

Atlanta's coal supply comes mostly from the Harlan, Cairnes, and adjacent districts in Kentucky, and from the Jellico field in Tennessee. Some steam coal is also furnished from the coal districts near Birmingham, Ala. The Kentucky and Tennessee coals seem to be of somewhat better quality than the available Alabama coal, and have consequently been preferred even though the freight rates are somewhat lower from Alabama fields.

Prior to the war and before the large rise in coal prices, Alabama coal sold for \$1.20 per ton for washed coal, f. o. b. mines, the freight rates to Atlanta being \$1.20 per ton. Kentucky and Tennessee coals cost an average of about the same, \$1.20 per ton, f. o. b. mines. The freight rate was \$1.45 from the Harlan, Ky., and Jellico, Tenn., fields. This made Alabama coal cost \$2.40 per ton, f. o. b. Atlanta, and Kentucky and Tennessee coal \$2.85 per ton.

The freight rates on coal at the time of the armistice was \$1.75 per ton (including the 3 per cent Government tax) from Birmingham, Ala., district and \$2 to \$2.10 per ton from Jellico, Tenn., and Harlan, Ky., districts. The coal price at the mine was \$2.55 to \$2.85 per ton, plus 15 cents per ton agent's commission, or \$2.70 to \$3 per ton. The price delivered in Atlanta was \$2.85, plus \$1.75, or \$4.60, per ton from Alabama and \$2.85 plus \$2.05, or \$4.90, per ton from Tennessee and Kentucky.

Using the same reasoning to determine future coal costs as given above in the discussion of coal situation for Gadsden and Warrior, Ala., it may be expected that coal for Atlanta will cost \$1.75 per ton f. o. b. mines, making a delivered cost of \$3.50 per ton from Alabama fields and \$3.80 per ton from the Tennessee and Kentucky fields.

There seems to be a strong opinion that the Alabama fields, which up to this time are not as well developed as those in Kentucky and Tennessee, will be used for the most part to supply Alabama's growing requirements and will not ship much coal to Georgia within the next 5 to 10 years or longer. If this is correct, and in view of the better grades that may be obtained from Kentucky and Tennessee, it seems reasonable to take the future cost of steam coal for Atlanta at \$3.80 per ton f. o. b. Atlanta.

APPENDIX E-8.

COST OF STEAM GENERATED POWER.

[With large modern steam turbine plants.]

For the purpose of this report and for comparison with hydroelectric power the cost of power plants and of power generation by large new steam plants to be located advantageously for coal and condensing water is figured for plants of 50,000 kilowatts to 100,000 kilowatts or more, as follows:

The cost of generating plants, with lands, buildings, and all equipment complete, up to and including 110,000-volt raising transformers, and including interest during construction and during the period of loading the plants, is figured at \$91 per kilowatt of installed capacity.

NOTE.—This is figured on the estimated prewar cost, including interest during construction and loading at \$65 per kilowatt, plus 40 per cent to meet estimated post-war increase on construction cost over prewar conditions.

If the steam plant is designed to supplement water-power plants with storage reservoirs, the water powers will provide emergency reserve or breakdown capacity to serve in case of temporary steam turbine generator failures. If such hydroelectric power is not available for emergency reserve, then spare capacity must be provided in the steam plants. The proportion of such spare capacity will depend on size of plants, the size of the generator units, and on other conditions.

For the purpose of this report, for large interconnected systems, it is estimated that when not relayed by water power such reserve generating capacity should be 15 per cent of the installed capacity, and under those conditions the cost of steam plants will be \$107 per kilowatt of power generated, and will include emergency reserve capacity of 15 per cent.

In determining the cost of power produced by steam plants 11.75 per cent of the cost of the plants is figured into the cost of power in addition to the cost of operation, maintenance, and administration. This 11.75 per cent is to cover interest, taxes, depreciation, and obsolescence. (See Appendix 5.)

NOTE.—11.75 per cent is used for steam turbine plants, whereas 10 per cent is set aside for those items in the case of hydroelectric plants, the difference being because of the more permanent nature of hydroelectric systems, including lands, dams, structures, etc., as compared with the physical parts of steam turbine plants.

The cost of administration and operation and maintenance of large steam turbine plants, to cover all labor and material expenditures except fuel, varies according to operating conditions and may be tabulated as follows:

Annual load factor of operation.	Kilowatt hours per year per maximum kilowatt load.	Yearly expenses per kilowatt of maximum load for administration, maintenance, and operation, except for fuel.
<i>Per cent.</i>		
30	2,600	\$4.10
55	4,800	4.66
80	7,000	5.10

NOTE.—Administration (executive and corporation) expenses is included in the above figures at about 40 cents to 60 cents per kilowatt per year. Interest charges on necessary operating capital at 20 cents per kilowatt are also included.

In addition to the administration, operation, and maintenance of steam plants (exclusive of fuel, as stated in the foregoing table), the coal consumption of such plants as we have under consideration, namely, superpower plants of modern design and located favorably for condensing water, etc., will be approximately as follows:

Coal consumption—Pounds per kilowatt hours and tons per year per kilowatt of maximum output.

Annual load factor on plant.	Kilowatt hours per year per kilowatt of maximum output.	Pounds of coal per kilowatt hours.	Tons of coal per year per kilowatt.	Thermal efficiency with coal of 13,500 B. t. u. per pound.
<i>Per cent.</i>				<i>Per cent.</i>
30	2,630	2.1	2.76	12.05
55	4,800	1.9	4.46	13.35
80	7,000	1.8	6.30	14.45

NOTE.—The steam plants of the southern power companies have to operate with condensing water having an abnormally high temperature for three to five months of the year. This increases the average yearly coal consumption over points where more favorable condensing water is available.

APPENDIX E-9.

ESTIMATED COST OF OPERATION, MAINTENANCE, AND ADMINISTRATION OF PROPOSED HYDRO OPERATING PLANTS, TRANSMISSION LINES AND SUBSTATIONS.

Alabama proposed Tallapoosa hydro plants, and double circuit 110,000 volt trunk line and sub-station, for 150,000 K. W. installed capacity.

Cost of operation and maintenance of three hydro plants for the Tallapoosa River, exclusive depreciation and obsolescence, is figured at \$35 090 per year for each plant, total for three plants.....	\$105, 000
Transmission line operation and maintenance is figured at \$135.00 per mile of tower line per year for double circuit steel tower 110,000 volt lines, to include all operation and maintenance, 240 miles at \$135.00.....	32,400
Substation operation and maintenance is figured as follows: For step-up substations, three stations at \$6,000 per year each.....	18, 000
Step-down substations are figured for two sub-stations at \$15,000 per year each.....	30, 000
Administration expenses for the three hydro plants, and transmission lines and substations as above, in addition to present administration expense of the Alabama Power Company.....	30, 600

Total for operation, maintenance and depreciation and administration of three Tallapoosa power plants..... \$216, 000

GEORGIA PROPOSED TALLULAH AND TUGALOO HYDRO PLANTS AND SINGLE CIRCUIT 110,000 VOLT TRUNK LINE AND SUBSTATION FOR 100,000 K. V. A. INSTALLED CAPACITY.

Cost of operation and maintenance of three plants on the Tallulah and Tugaloo Rivers, exclusive of depreciation and obsolescence, is figured at \$35,000 per year for each of two plants and \$30,000 per year for one plant, total for three.....	\$100, 000
Transmission lines operation and maintenance is figured at \$125 per mile of tower line per year, for single circuit steel tower, 110,000 volts, 50 miles at \$125.....	11, 250
Substation operation and maintenance is figured as follows: For three step-up stations at \$6,000 each.....	18, 000
For one step-down station at \$20,000.....	20, 000
Administration expense for the new hydro plants, transmission lines and substations, in addition to the present administration expense of the Georgia power companies, is figured as.....	25, 750

Total for operation, maintenance and administration..... 175, 000

APPENDIX E-10.

UNDEVELOPED POWER SITES CONSIDERED IN GEORGIA.

Bartlett's Ferry development.—Above the present Goat Rock power plant on the Chattahoochee River there is an undeveloped site with an available head of 119 feet. A dam of this height will provide an appreciable amount of fore-bay storage. The initial installation would be 36,000 kilowatts.

Mathis development.—The construction of a 12,000-kilowatt hydro plant at Mathis, using water from the present Mathis Reservoir of the Georgia Railway & Power Co. at 189 feet to 100 feet (average 175 feet) to the headwater of the Tallulah Falls plant.

Tugaloo development.—The construction of a dam on the Tugaloo River about 2 miles below the present Tallulah plant. This is called the Tugaloo plant and would have 45,000 kilowatts installed and a working head of 135 feet.

Ralston development.—The construction of a 40,000-kilowatt plant at Ralston, on the Tugaloo River, about 5 miles below the proposed Tugaloo plant. This plant would have an effective head of 100 feet.

NOTE.—The proposed Tugaloo and Ralston plants would receive all the water from the Tallulah Falls (regulated by the Burton Reservoir, which is now building, with a capacity of 5,000,000,000 cubic feet, and the present Mathis Reservoir, 1,370,000,000 cu. ft.); also they would get all the water from Chatooga River, which would be regulated at such time as the Earls Ford Reservoir mentioned below is built.

Chatooga River development.—Other proposed developments were considered, including four water powers on the Chatooga River combined with a proposed 5,000,000,000 cubic-foot storage reservoir at Earls Ford. These four developments have been suggested according to the following table of installation and annual output.

Chatooga developments.	Head feet.	Installed capacity kilowatts.	Yearly output kilowatt hours (without Earls Ford reservoir).
No. 1.....	107	20,000	54,000,000
No. 2.....	115	20,000	57,000,000
No. 3.....	224	30,000	88,000,000
No. 4.....	135	15,000	46,000,000

We have no detailed cost estimates on the proposed Chatooga powers, but are informed that the lands can be acquired and the dams and buildings constructed and electric apparatus installed for about \$75 per kilowatt based on prewar costs, or with a 40 per cent advance over prewar costs, \$105 per kilowatt.

It should be borne in mind that if the Earls Ford Reservoir should be constructed it would improve the river flow not only at the proposed Tugaloo and Ralston developments, but also at the existing development at Augusta and at the possible development at Calhoun Falls, in addition to increasing the output of the proposed Chattooga River plants above.

APPENDIX E-11.

POWER AVAILABLE FROM THE TALLAPOOSA RIVER DEVELOPMENTS IN YEAR OF EXTREME LOW WATER FLOW WHEN OPERATED IN COMBINATION WITH ALABAMA POWER CO.'S PRESENT SYSTEM.

The year 1904 was the year of lowest recorded stream flow. The run-off of the Coosa and Tallapoosa Rivers during 1904 would have produced 263,000,000 kilowatt hours at Lock 12 with an installation of 80,000 kilowatts and 314,000,000 kilowatt hours in the proposed Tallapoosa developments with a storage capacity of 270,000,000 kilowatt hours and an installation of 150,000 kilowatts. By producing 55,000 kilowatts of steam power continuously, the above power in water will make it possible in a year of water flow similar to 1904 to produce a continuous output of 126,500 kilowatts and an average peak load of 190,000 kilowatts, on the basis of a weekly load factor of 67 per cent. The installed capacity and storage capacity would permit carrying an occasional peak load of 230,000 kilowatts, so long as the average load for the year does not exceed 126,500 kilowatts (1,110,000,000 kilowatt hours yearly). The following tabulation itemizes the source of water and steam power and the amount of potential power in kilowatt hours remaining in reservoir at the beginning of the year, at the end of each month, and at the end of the year

under 1904 conditions of river flow, assuming that at the first of the year the capacity of the Cherokee Reservoir available with a 50-foot draw down was only half filled.

Data, 1904. (Driest year.)	Kilowatt hours in storage on Tallapoosa River first of month.	Water in storage, per cent of the capacity of the reservoir with 50 feet draw down.	Kilowatt- hour flow into the Tallapoosa storage during the month.	Kilowatt hours pro- duced by steam dur- ing the month (60,000-kilo- watt plant).	Kilowatt hours pro- duced by Lock 12 and Jack- son Shoals during month.	Kilowatt hours taken from Tallapoosa storage dur- ing month (see note below).	Kilowatt- hours total generated.
		<i>Per cent.</i>					
January.....	136,500,000	50.0	24,400,000	40,900,000	24,050,000	- 4,150,000	102,500,000
February.....	122,350,000	48.4	51,000,000	36,920,000	34,500,000	+37,400,000	85,000,000
March.....	169,750,000	62.2	38,000,000	28,900,000	52,100,000	+24,800,000	94,200,000
April.....	194,550,000	71.3	23,400,000	39,600,000	23,100,000	+ 5,000,000	91,100,000
May.....	199,550,000	73.0	13,600,000	40,900,000	16,900,000	-22,800,000	94,200,000
June.....	176,750,000	64.7	14,400,000	29,600,000	16,000,000	-12,000,000	82,000,000
July.....	164,750,000	60.2	14,900,000	40,900,000	15,200,000	-12,900,000	84,900,000
August.....	150,850,000	55.2	80,400,000	40,900,000	28,160,000	+55,250,000	94,200,000
September.....	206,100,000	75.5	11,300,000	39,600,000	8,720,000	-31,420,000	91,100,000
October.....	174,680,000	63.9	4,320,000	40,900,000	6,180,000	-42,800,000	96,200,000
November.....	131,830,000	48.2	9,580,000	39,600,000	7,630,000	-34,290,000	91,100,000
December.....	97,690,000	35.7	21,500,000	40,900,000	23,550,000	-17,550,000	103,500,000
January, 1905..	80,040,000	29.5					
							1,110,000,000

¹ Total, 12 months.

NOTE.—+Indicates added to storage; —Indicates taken from storage.





APPENDIX F

Report to the Chief of Engineers, U. S. Army, dealing
with the Electric Power Problems on
the Pacific Coast

Submitted by MAJ. GEORGE F. SEVER, Engineers, U. S. Army
Washington, D. C., March 26, 1919



ELECTRIC POWER PROBLEMS ON THE PACIFIC COAST.

POWER CONDITIONS IN SEATTLE, WASH.

1. The Puget Sound district, in which Seattle is the largest industrial center, is served by three electric-power systems, consisting of the Puget Sound Traction, Light & Power Co., the municipal system of Seattle, and the municipal system of Tacoma. The investigation of this district in June and July, 1918, showed that there was great industrial activity in Seattle and Tacoma, in the matter of ship-building, machine shops, electric railways, electric furnaces, milling, and foundry work. These manufacturing interests were being served from the electric-power systems above mentioned, and there was considerable rivalry in the securing of customers between the Puget Sound Traction Co. and the Seattle municipal system. In Tacoma the Puget Sound Traction Co. and the Tacoma municipal system were electrically connected, and a contract existed between the two systems for the transfer of as much as 10,000 kilowatts under certain conditions of operation. In Seattle there was no electrical connection nor contractual relationship between the Seattle municipal system and the Puget Sound Traction Co. The two systems were operated absolutely independently, and the two high-tension portions of the systems were of different voltages and character, although of the same frequency.

2. The investigation of the connected loads and also of the prospective loads showed that there was anticipated a considerable growth on the traction company's system as well as on the Seattle municipal system, and the city was seeking to secure an additional hydroelectric development on the Skagit River, approximately 110 miles away from the city. So long as the city operated as a separate entity and took contracts at a considerably lower rate than that set by the Puget Sound Traction Co. there was justification for additional hydroelectric development to meet the growing demands on their system, and it was also desirable that some development of this character should be made under the above circumstances to assist in the elimination of the consumption of fuel oil used by the Lake Union steam plant.

3. However, there was not a shortage of power on the system of the traction company, and it was clearly shown that by combining the capacities of the three power systems in this territory the diversity thus secured, together with the excess capacity on the traction company's system, would enable a considerable load to be added to the combined networks and not produce a serious deficiency in this section. It was recommended that suitable interconnections be made so that all three systems could be operated more or less as one system and a 10,000 kilowatt hydroelectric-power development be carried

out by the Puget Sound Traction Co, bringing this power into use within approximately a year after the work had been started. This would have amply met the demands on the systems and would have served as an important factor in eliminating the use of fuel oil in the Lake Union steam plant of the Seattle municipal system.

4. In connection with the desirability of conserving fuel oil, it was shown that the Lake Union steam plant would probably burn during 1918 a maximum per day of 1,600 barrels of oil and a minimum per day of 600 barrels. If the average per day for a year is taken at 1,000 there would be used approximately 365,000 barrels of oil per year. The price of oil in the summer of 1918 was \$1.85 per barrel, therefore, the cost of this fuel for a year at that unit price would be \$675,250. From the figures gathered in Seattle and submitted by the municipal power department, it is shown that 1 barrel of oil will develop, including the stand-by use, 184 kilowatt hours. On the basis of this cost of oil, it is clearly shown that the production cost of a kilowatt hour is 1 cent for fuel, and with the other charges added to this, the cost of production of a kilowatt hour by steam is high and argues strongly for the elimination of fuel oil for this purpose. This might easily be secured through the interconnection of the largely developed hydroelectric system of the traction company to the Seattle municipal system. It is understood that this is now being accomplished through the cooperation of the traction company and the municipal system of Seattle, and the insistence of the capital issues committee at Washington when authority was granted by them to the city of Seattle for the issuance of \$5,500,000 in bonds for the starting of the construction of the hydroelectric development for the city on the Skagit River. In view of the absolute necessity for the elimination of the use of fuel oil for electric power production, early hydroelectric development should be concluded and the Lake Union steam plant be simply used as a stand-by for the interconnected systems in the Puget Sound district.

5. The traction company has a number of hydroelectric developments that can readily be made if the industrial demands require additional hydroelectric development, the city of Seattle is proceeding with its Skagit River hydroelectric development, and the city of Tacoma has recently purchased a hydroelectric development at Lake Cushman on the Skokomish River. If all of these are developed, they will tend, to a large extent, to eliminate the use of fuel oil.

6. The Georgetown steam station of the traction company has a continuous capacity of 23,000 kilowatts, and is sufficient to act as a voltage regulator and to some extent as an emergency station and for handling the peaks on the interconnected systems. This station has during the last year been changed over from fuel oil to coal burning.

7. The city of Tacoma has a splendid up-to-date hydroelectric system, which derives its supply from the Nisqually River, which is fed from a glacier of the same name on Mount Rainier. The character of the river is such that there is a great difference between the high and low flows in the stream, and it is necessary at times for the Puget Sound Traction Co. to supply the city with power, at other times the city supplies the traction company with excess up to 10,000

or more kilowatts. Steps are being taken by the city of Tacoma to secure reservoir rights on the upper Nisqually so as to regulate the flow of the stream for the operation of the power plant. The city of Tacoma has no steam auxiliary as has the city of Seattle.

8. In this territory there are many possibilities for the development of hydroelectric stations, and, in view of the often reiterated statement that fuel oil should be eliminated for use in public utilities, early efforts should be made to make hydroelectric developments of sufficient capacity to handle not only the increasing industrial load but to eliminate the use of fuel oil.

PORTLAND, OREG.

9. In the industrial territory in and about Portland, electric power service is rendered by the Portland Railway Light & Power Co. and the Northwestern Electric Co., and these two systems are electrically interconnected and give and take power under contractual relationship. They assist each other when accidents occur and work harmoniously, although they are competitors in a business way. The Portland Railway Co. in July, 1918, had a large industrial load, consisting of shipbuilding plants, machine shops, the street railway, and a great variety of industrial customers, including many office buildings and services of like character. It had a number of hydroelectric stations, two of which were on the Clackamas River, without storage, and another station on the Bull Run River, which also had no storage provision. It had steam stations, which were equipped for burning both coal and hog fuel (that is, the refuse from sawmills). Owing to the large industrial growth in this territory, it was running with a very small surplus, and it was estimated that there would need to be added to the system within a year or less at least 10,000 kilowatts, and recommendations were made that an additional hydroelectric plant should be built on the upper portion of the Clackamas River. However, it could not be accomplished, owing to financial stringency, although the Shipping Board stood ready to assist to some degree in furthering this project.

10. The Northwestern Electric Co. has a hydroelectric plant on the White Salmon River which transmits power to Portland where it connects with a steam plant using fuel oil, installed in the Pittock Building in the center of the city. It has also erected a steam station on the banks of the Willamette River alongside of a sawmill and intends to use both fuel oil and hog fuel in the operation of this plant. Naturally this generating station will be tied into the general electrical system of this company. There is used in this center a considerable amount of fuel oil which should be eliminated in so far as possible by the development of additional hydroelectric stations, and owing to the character of the rivers upon which these stations are placed there should be developed some storage capacity if it can be done within reasonable cost. During this last year, owing to the great shortage of water for the operation of the hydro plant, additional amounts of fuel oil and other fuel had to be consumed, making the cost of operation considerably higher than heretofore.

11. Besides these two systems there is in this vicinity the Pacific Power & Light Co., which lies considerably east of Mount Hood but is connected to the system of the Northwestern Electric Co. at their plant on the White Salmon River.

CALIFORNIA.

12. The problem in California is one of providing ample electric power for meeting the industrial growth of the various communities up and down the State and at the same time making sufficiently increased developments so as to eliminate the consumption of fuel oil. The best authorities in their opinion have indicated that the price of fuel oil will probably not fall materially, owing to the decreasing amounts of fuel oil available and the small amounts that are being given by each well as it comes into service. There will be an insistent demand for fuel oil for the operation of the Naval Establishment and the ships of the merchant marine, and every step should be taken by the authorities to stimulate the development of hydroelectric projects whose use would eliminate the consumption of fuel oil in public utility plants on the Pacific coast. Steps are being taken by some of the public utility plants to develop the use of powdered fuel in their present steam generating stations, but this is at the present moment only in the experimental stage on the Pacific coast.

13. It is interesting to contemplate what will happen in California when oil is largely eliminated from public utility operations and, so far as is possible, from industrial processes which can use in its stead powdered coal or hydroelectric power. When oil is withdrawn it will be absolutely necessary for the life of the communities to have available an ample supply of hydroelectric power and powdered coal burning appliances for the production of steam-generated electric power. The earlier this is accomplished the greater will be the conservation of the natural resource—oil. In order that this may be brought about, it is necessary for the public utility to be encouraged in its development of hydroelectric possibilities, and one step in this program is the passage by Congress of a water-power bill which will remove for a considerable time any doubt as to the possible conditions surrounding the control of hydroelectric developments by the Government, when these developments use, in whole or in part, any public lands or forest reserves.

14. There is also another important matter which should be considered by those commissions which have control over public utility corporations, and this is some method as to control of rates and control of return on investment to the end that the promoters of these public utility companies may develop some incentive for establishing internal economies, so as to decrease rates to consumers and at the same time to increase the return which might be made on the investment. It seems that this is particularly important in connection with those States where fuel oil, or other fuel which is difficult to obtain, must be conserved. Under the present laws or customs in these States the consumers' rates are established so as to give a fixed return on the public utility investments. While this is good in itself, it does not recognize what might be done in the way of internal economies in the operation and maintenance of the companies. In view of the fact that it is absolutely necessary to conserve oil and coal and that this situation has obtained for some years, attention should be given to establishing some other principle than that which seems now to obtain in the deliberations of the public service or railroad commissions.

15. In the case of a number of companies serving the same territory and thereby establishing a competitive situation, one of these companies might, through internal economies and prudence in operation, be enabled to reduce its rates and acquire a largely increased load and consequently greater return on its investment. The other companies serving the same territory and operating under the same conditions would be free likewise to derive the same benefits as the first company. If, however, this could not be brought about, the natural result of the establishment of proper operating conditions would lead to the closer mutual operations and interconnection of these companies and eventually to the merging of these companies or to the assignment of districts in which their operations would be conducted. The more natural and logical arrangement would be to have such companies under the control of one organization, thus making for the more efficient utilization of material and the reduction of capital expenditures.

16. In California the above ideas could readily be carried out in connection with the large power systems both in the northern and southern parts of the State. It would be necessary, however, to place the operation of municipal light and power companies under the control of the State railroad commission if success is to come to all organizations serving the public with electric energy.

HYDROELECTRIC POSSIBILITIES.

17. The three States on the Pacific coast, Washington, Oregon, and California, have, respectively, 16 per cent, 12.3 per cent, and 14.5 per cent of a total of 54,000,000 horsepower of water-power resources in the United States, in accordance with figures recently compiled by Mr. O. C. Merrill, chief engineer, Forest Service, United States Department of Agriculture. The total of these three States amount to 42.8 per cent of the above total water power in the United States. Further, according to Mr. Merrill's figures, there have been installed 3,400,000 horsepower in water wheels, steam engines, and gas engines in commercial and municipal central stations, street and electric railways, and manufacturing plants; but there yet remain, over and above this, hydraulic resources amounting to 23,100,000 horsepower in the three Pacific States.

18. It is undoubtedly a fact that in those places where fuel oil is now used for the generation of electric power hydroelectric developed power could be readily and easily substituted. If oil for public utility operations were suddenly cut off, the industrial life of California would receive a serious blow and would not recover until hydroelectric developments could be secured to take the place of electric power previously generated through the utilization of fuel oil. Consequently it behooves all the industrial interests in the State of California to take cognizance of this situation and to lend their support, at the earliest date possible, to every justifiable endeavor to develop hydroelectric projects for public utility operations. When one considers how important the electric-power supply is to all industrial centers and communities in the State and how dependent every small item in these communities is upon the securing of a con-

tinuous supply of electric power, it will be readily seen that this is no theoretical situation but a hard fact which demands immediate attention.

GEOGRAPHICAL LOCATION OF WATER POWERS.

19. In the northern part of the State there is located the Klamath River, which is fed to a large extent from Klamath Lake and the drainage area which lies below the lake. This has a rather large minimum stream flow and steps are being taken to regulate the river by the installation of a dam at the southern end of Klamath Lake. On this river at Copco is installed a dam and a power station owned by the California-Oregon Power Co. It also has a power station on the Rogue River in Oregon, which is also a stream with a fairly large minimum flow. Both of these rivers have large additional power opportunities, but there is no industrial district to absorb the large power that can be developed.

20. The next river of large importance is the Pitt, which has a minimum stream flow in the vicinity of Sheep Rocks of approximately 3,000 second-feet and a maximum approximating 30,000 second-feet. This river lends itself excellently to very large power developments and there is ample assurance that the installation of power stations with a large constant generating capacity can be developed in many places along the river. This river has its source in the lava territory between Mount Shasta and Mount Lassen, and is fed from large underground water storages, as shown by the large springs that feed not only the river itself but the creeks which are tributary to the river. Attempts have been made to develop power stations on the Pitt River by the large power companies in California, but nothing has yet been done of any moment although there are developments being projected and one is being worked on, to the end that it may be brought in within a period of about two years. The Pacific Gas & Electric Co. has a development at the Big Bend of the Pitt River which if successfully completed will generate approximately 200,000 kilowatts and would be transmitted to the industrial district of the San Francisco Bay.

21. As one proceeds southerly it is found that the Feather River is the next one in importance in that it also derives a steady stream flow from the lava beds south of Mount Lassen. The drainage area from which the water goes into Lake Alamanor, of the Great Western Power Co.'s system, is large and there are many possibilities for additional power developments on the middle fork of the Feather River. One is now being projected and would develop 40,000 kilowatts.

22. In proceeding southwardly from this point there is found the Yuba River and the Stanislaus, both of large flow in a granite country, but do not possess the storage possibilities such as those rivers do that have their origin in the lava country in the north. For this reason it has been found necessary to provide storage basins or reservoirs to retain the quick run-off that occurs in this granite country. These reservoirs are expensive, as they require either rock fill or gravity, or some other type of approved dam, and, further, entail the purchase of a considerable area of land and also may fall within the domain of the public lands. In the southern part of the State and

in that territory occupied by the San Joaquin Light & Power Corporation, the Southern California Edison Co., and the Southern Sierras Co., it is necessary to provide storage reservoirs on account of the quick run-off from the streams from which the water is derived. There is no large natural underground storage such as exists in the northern part of the State.

23. There are ample hydroelectric power possibilities to take care of all the steam-generated power now used by the public-utility corporations, and it can be seen that if these are developed many millions of barrels of fuel oil can be saved each year, and the operating expenses of the power companies can be reduced and excellent results on the increased investment assured. The return of the total investment will probably be made much larger.

FUEL OIL.

24. One of the most important factors in the operation of the companies has been the increased use of fuel oil at rapidly increasing prices. The price of fuel oil had risen from 60 cents per barrel in August, 1916, to \$1.20 in January, 1917, and to \$1.60 in April, 1918. It is desirable to discontinue the use of fuel oil at the earliest possible moment, in order to reduce operating expenses as well as to conserve the fuel-oil supply. In 1917 three power companies serving the central and northern territory consumed 1,391,478 barrels for electric supply only. If the average price had been \$1.34 per barrel, the cost for this fuel would have been \$1,864,000 per annum. The consumption of these three companies for the first eleven and one-half months of 1918 has been 1,998,194 barrels, and if the assumption is made that the same rate obtains for the last half of December as for the first half, the consumption for the year 1918 will be 2,047,303 barrels. The average price during 1918, outside of contracts made at lower rates, is \$1.55 per barrel, so that the total cost of the oil burned by these three companies in 1918 is \$3,180,000. Much of this can and should be saved through the early development of hydro power. At an average rate of 200 kilowatt hours per barrel of oil, the above amount would have developed 409,460,600 kilowatt hours. Reference will be made to this in discussing the proposed hydroelectric developments.

25. In the southern part of the State seven power companies in 1917 generated 242,149,000 kilowatt hours by steam stations. If all of these kilowatt hours had been generated by fuel oil and the average kilowatt hour per barrel was 200, there would have been used 1,210,745 barrels of oil. Some natural gas was used at some stations, so that the fuel-oil consumption was not quite as great as indicated above. However, 1,000,000 barrels is a safe figure for use, and if the same rate of increase occurred in 1918 as for the three companies serving the central and northern part of the State the consumption would reach 1,507,000 barrels. Thus the total amount used in 1918 by the companies mentioned would be 3,554,303 barrels. At the unit price of 1918—\$1.55 per barrel—this would cost \$5,500,000.

26. On the system of the San Joaquin Light & Power Corporation there were used for 1917, 98,783 barrels of oil and for the first 10 months of 1917, 68,360 barrels. For the first 10 months of 1918,

204,630 barrels of oil were burned, so that using the ratio of the 10 months of the two years to estimate the total for 1918, it is found that 296,000 barrels were used. Besides this fuel, 806,949,138 cubic feet of natural gas were burned during the first 10 months of 1918 as compared with 34,447,000 cubic feet in 1917. About one-quarter of their generating capacity is in steam, with 815 kilowatts in direct gas and oil.

RECOMMENDATIONS.

PACIFIC GAS & ELECTRIC CO.—HYDRO DEVELOPMENTS.

27. After a careful inspection of the various developments, the writer's recommendations as to the work that should be done on the Pacific Gas & Electric System are the raising of the dam at Fordyce Lake 21 feet so as to add 11,800 acre-feet of storage, this water being spilled into Lake Spaulding and then put through the Spaulding-Drum-Halsey and Wise power stations, and later, in time, through a No. 2 station which is recommended to be built. The Fordyce Dam is of the rock-filled type, with a wooden facing, and the 21 feet increase in height is the most economical construction that can be secured. If it should be raised a greater height, there would be required a largely increased expenditure, which is not now warranted.

28. The second item is the raising of Lake Spaulding Dam 10 feet so as to add 6,423 acre-feet to the storage in this important reservoir. The additional water is intended to be passed through the Drum and other stations mentioned above, and also the No. 2 station, the construction of which is in contemplation. Besides these two increases in storage capacities, there is what is known as the "Bowman-Spaulding project," which will add a large storage capacity to the system, and the water would be spilled into Lake Spaulding. The building of a No. 2 station on the Bear River, with a capacity of 25,000 kilowatts, will, together with the present stations and the additional storage, provide 233,101,000 additional kilowatt hours to the Pacific Gas & Electric Co.'s system. The cost of these improvements is approximately \$7,200,000.

STEAM.

29. In addition to these hydro developments on the Pacific Gas & Electric Co.'s system there will be installed in Station A in San Francisco and Station C in Oakland the full complement of boilers, so as to make the electric-generating apparatus fully available. The cost for these steam additions will be approximately \$525,000. This investment has been provided for and is not included in the \$7,200,000 noted above. Heretofore the practice has been on this coast to equip a steam station with a number of boilers to operate generating machinery only sufficient to give good regulation, to take a portion of the load in case of trouble on the transmission line, and to handle the peaks during the so-called rush hours. It is also used to build up load which later can be transferred en bloc to a hydro plant which meanwhile has been under construction. Table I shows the details of the proposed developments on this system:

TABLE I.—*Pacific Gas & Electric Co.*

Item.	Added storage.	Kilowatt hours per year additional energy available with present installations.	Kilowatt hours per year additional energy available after new power house is installed.	Total cost.	Value of energy output at $\frac{1}{2}$ cent per kilowatt hour.	Per cent return on investment based on value of $\frac{1}{2}$ cent per kilowatt hour.	Barrels of oil saved per year (at 200 kilowatt hours per barrel).
Construction No. 2 power house, Bear River.....	<i>Acre-feet.</i> 125,000	(A)	(B) 92,500,000	\$5,184,300	\$308,333.00	6.5	462,500
Raising Fordyce Dam 21 feet.....	11,800	17,700,000	26,550,000	300,000	88,500.00	36.7	132,750
Raising Spaulding Dam 10 feet.....	6,423	9,684,500	14,451,700	150,000	48,172.30	43.0	72,260
Bowman-Spaulding project.....	42,275	69,600,000	99,600,000	1,566,000	332,000.00	22.1	498,000
Total.....	60,498	96,984,500	233,101,700	7,200,300	777,005.30	10.79	1,165,510

¹Kilowatts.

THE GREAT WESTERN POWER CO.

HYDRO DEVELOPMENTS.

30. The next important addition to the power supply is that of the Great Western Power Co. in their proposed development of a 40,000-kilowatt station on the Feather River at Butt Valley. It is proposed to run a tunnel 11,800 feet long from Lake Almanor into Butt Valley and thence by another tunnel 10,400 feet long to the point of drop of 1,155 feet into the power station located in the foot of the canyon of the Feather River. This project will cost in the vicinity of \$6,000,000 and will take about two to two and one-half years to construct. For the purpose of comparison it has been assumed throughout that a net return of one-third cent per kilowatt hour, exclusive of fixed charges, may be obtained for the power.

31. Table II illustrates the results which may be accomplished by this development.

TABLE II.—*The Great Western Power Co. hydro developments.*

Generating capacity.	Kilowatt hours generated.	Load factor, per cent.	Kilowatt hours sold to consumers generated by 75 per cent efficiency.	Value of energy output at $\frac{1}{2}$ cent per kilowatt hour.	Per cent return on investment.	Barrels of oil saved per year at 200 kilowatt hours per barrel, estimated.
40,000 kw..	350,400,000	100	265,000,000	\$1,166,000	19.45	1,752,000
.....	265,000,000	75	199,000,000	833,333	14.60	1,325,000
.....	175,000,000	50	131,400,000	586,666	9.72	875,000

SIERRA & SAN FRANCISCO POWER CO.

HYDRO DEVELOPMENTS.

32. The Sierra & San Francisco Power Co. has its power stations and reservoirs in and about the Stanislaus National Forest Reserve and on the Stanislaus River. This company is in a position to supply power at the earliest date. It has two reservoirs in operation known as the "Relief" (14,965 acre-feet) and "Strawberry" (17,900 acre-feet). It has in prospect another reservoir known as "Big

Dam" (16,654 acre-feet), which would spill its water into "Strawberry." At the present time water from the South Fork of the Stanislaus and the "Strawberry" reservoir is running in what is known as the "Philadelphia Ditch," at the rate of 50 second-feet, which spills from a height of 1,860 feet at Spring Gap into the Middle Fork of the Stanislaus River, and is diverted at the Sand Bar Dam into the present flume leading to the Stanislaus power station. It is proposed to put a power station at the foot of this present spillway near Bakers Crossing to contain a 9,000-kilowatt generator, and later, when the size of the ditch has been increased to accommodate 100 second-feet, to add another 9,000-kilowatt unit at this station, thus giving 18,000 kilowatts additional hydro development. At the same time an increase in the capacity of the penstocks at the Stanislaus power station will gain 7,000 kilowatts which is now lost in friction head. This will make available the total installed capacity of 40,000 kilowatts at the Stanislaus power station.

STEAM.

There is also contemplated, in connection with the North Beach steam station of the company in San Francisco, an increase in the boiler capacity so as to make the three 9,000-kilowatt units at present installed available for full operation. The cost of these additions will approximate \$3,000,000 and will take from one year to three years for the completion of the individual details.

34. The details of these developments are shown in the following Table III.

TABLE III.—*Developments on the Sierra & San Francisco Power Co.*

Location of developments and year of completion.	Character of development.	Increased kilowatt hours per annum.	Cost estimated.	Barrels of oil equivalent at 200 kilowatt hours per barrel.	Value at 1 cent per kilowatt hour.	Per cent return on investment.
Spring Gap No. 1, 1 year.	18,000 kilowatt, 20-mile line to Stanislaus and first 9,000 kilowatt generator.	¹ 49,000,000	\$750,000	245,000	\$163,333.00	21.81
Spring Gap No. 2, 24 years.	Second 9,000 kilowatt generator, transfer line, Stanislaus to Manteca.	49,000,000 ² 19,710,000	400,000 200,000	.....	.....	.....
	Increase Philadelphia ditch to 100 second-feet.	68,710,000	40,000	.....	.....	.....
Stanislaus plant....	Add new pipe line at plant to reduce friction loss.	15,000,000	640,000 125,000	343,500 75,000	229,030.00 80,000.00	35.8 40.0
Big dam.....	Erect dam at Big Dam 16,700 acre-feet.	.....	750,000	.....	.....	.....
North Beach, San Francisco.	4,500 horsepower in boilers to be added to give 11,000 kilowatts.	³ 24,000,000	200,000	⁴ 120,000	80,000.00	40.0
		.....	⁵ 245,500	.....	.....	.....
Total.....	.....	182,710,000	2,711,000	663,500 120,000 ⁶ 543,500	522,369.00	19.26

¹ 62 per cent load factor.

² Stanislaus, due to 50 second-feet added at 50 per cent load factor.

³ At 25 per cent load factor.

⁴ Added barrels.

⁵ Contingencies.

⁶ Net.

FUEL OIL USED BY PACIFIC GAS & ELECTRIC CO., GREAT WESTERN POWER CO., AND SIERRA & SAN FRANCISCO POWER CO.

35. It is of interest to record the amount of fuel oil used during the year 1918 and the kilowatt hours developed by the steam plants of the three companies. Table IV shows this in detail:

TABLE IV.—Table showing the barrels of oil used and kilowatt hours generated by steam during 1918, and kilowatt hours available by development.

Company.	Kilowatt hours generated by steam (estimated).	(a) Barrels of oil burned to Dec. 15, 1918, inclusive. (b) Estimate for year of 1918.	Kilowatt hours from new developments (estimated).
Pacific Gas & Electric Co.....	312,000,000	{ (a) 1,136,072.15 (b) 1,168,100.38 }	233,101,700
Great Western Power Co.....	92,500,000	{ (a) 468,547.00 (b) 472,620.00 }	199,050,000
Sierra & San Francisco Power Co.....	71,700,000	{ (a) 393,575.00 (b) 406,473.00 }	132,710,000
Total.....	476,200,000	{ (a) 1,998,194.15 (b) 2,047,203.00 }	564,861,700
			564,861,700
			476,200,000
			¹ 88,661,700

¹ Surplus; 19.55 per cent excess over kilowatt hours generated by steam in 1918.

The kilowatt hours from the proposed new developments will more than equal the kilowatt hours generated by steam in 1918. Thus, the kilowatt hours from the proposed hydro developments not only can be employed to replace much of the steam-generated kilowatt hours but also the kilowatt hours required to meet the yearly increase in demands for power on the systems.

36. The approximate total of the three central and seven southern companies' oil consumption for 1918 will be around 4,000,000 barrels, or 4 per cent of the total output of California fields in 1918, and at the average price of \$1.55 would equal \$6,200,000 for this part of the fuel supply for these California companies. The development of additional hydro power would cut this expenditure down to a very much smaller amount and much of this operating expense would cease.

GENERATING CAPACITY AND MAXIMUM DEMANDS.

37. Data of the Pacific Gas & Electric Co., Great Western Power Co., and Sierra & San Francisco Power Co. for certain conditions are given below.

38. The following tables, Va and Vb, show for each system and the total combined systems the surplus kilowatt under the most favorable condition of hydro and steam generation, and also the most unfavorable conditions of the generating capacity. In each case the actual maximum demand for 1917 and 1918 and the estimated maximum demands in 1919 and 1920 are deducted from the best and the worst possible conditions. The difference shows the surplus and the deficiency in each case.

TABLE Va.—*Pacific Gas & Electric Co.*

Date.	Hydro.		Steam.		Capacity.	
	High water.	Low water.	Normal rating.	2 hours sustained.	Favorable.	Unfavorable.
	122,000	90,000	75,000	60,000	197,000	180,000
	Maximum kilowatts demand.	Surplus under favorable conditions.	Surplus under unfavorable conditions.			
1917.....	158,270	28,780	18,270			
1918.....	174,100	22,900	124,100			
1919.....	191,500	5,500	141,500			
1920.....	210,000	113,000	160,000			

¹ Deficiency.TABLE Vb.—*Great Western Power Co.*

Date.	Hydro.		Steam.		Capacity.	
	High water.	Low water.	Normal rating.	2 hours sustained.	Favorable.	Unfavorable.
	70,000	55,000	23,950	21,750	98,950	77,750
	Maximum kilowatts demand.	Surplus under favorable capacity.	Surplus under unfavorable capacity.			
1917.....	75,400	18,550	2,350			
1918.....	75,480	18,470	2,270			
1919.....	82,500	11,450	14,750			
1920.....	87,000	6,950	19,250			

¹ Deficiency.TABLE Vc.—*Sierra & San Francisco Power Co.*

Date.	Hydro.		Steam.		Capacity.	
	High water.	Low water.	Normal rating.	2 hours sustained.	Favorable.	Unfavorable.
	36,320	10,800	17,000	20,000	53,320	30,800
	Maximum kilowatts demand.	Surplus under favorable conditions.	Surplus under unfavorable conditions.	124,000		
1917.....	45,270	8,050	114,470			
1918.....	46,934	6,385	116,134			
1919.....	50,645	2,675	119,845			
1920.....	54,645		123,845			

¹ Deficiency.

TABLE Vd.

Date.	Combination of three companies.			Remarks.
		Favorable.	Unfavorable.	
	Capacity....	344,270	258,550	.....
	Maximum demand.	Surplus under favorable conditions.	Surplus under unfavorable conditions, 100 per cent.	
1917.....	278,940	65,330	¹ 20,390	No diversity considered.
1918.....	296,514	47,756	¹ 27,964	Do.
1919.....	324,645	19,625	¹ 66,095	Do.
1920.....	351,645	¹ 7,375	¹ 63,095	Do.

¹ Deficiency.

39. In Table Vd, which is the summary of the individual columns, there is shown to be in 1919 under the most favorable conditions and without taking into consideration the diversity between the three systems a surplus of 19,625 kilowatts, which is only 6½ per cent of the total maximum demand, and under the very worst conditions that would obtain in that year, on the assumption that the water is low and every bad condition is coincident there would be a deficiency of 66,095 kilowatts. In 1920 the conditions are even worse unless additional equipment is provided. Actual conditions that will obtain lie somewhere between the most favorable and most unfavorable, and it must be clearly understood that the most unfavorable conditions will probably never exist.

40. The deficiency in power during the last year approximated 25,000 kilowatts for safe operating, and as the normal growth is between 20,000 and 25,000 kilowatts there is great need for increased generating capacity. Besides there is the further need for the replacement of the use of fuel oil by hydroelectric development, and this should be carried out at the rate of about 50,000 kilowatts per annum until the oil-generated power is reduced to a safe and economical value.

NORTHERN AND CENTRAL DEVELOPMENTS NOT IN WAR-TIME PROGRAM.

41. Besides the previous developments, which are recommended on the basis of a war-time program, there are many other available hydropower developments, some of which have been carefully considered, but they have not been thought sufficiently worthy of recommendation on the basis of war-time service. Among these might be mentioned the projects on the Big Bend of the Pitt River, of the Pacific Gas & Electric Co., and the Northern California Power Co.; the Fall River development, between Fall River and Pitt River, and also the various smaller projects on the Pitt River and its tributaries; the additional developments on the North Fork of the Feather River, owned or controlled by the Great Western Power Co., the first project in connection with the Hetch Hetchy water supply,

which will take approximately three years to develop; and other smaller developments which can be secured on the Pacific Gas & Electric Co.'s system in the central part of the State.

42. The cost of the developments on the Pacific Gas & Electric Co., Great Western Power Co., and Sierra & San Francisco Power Co. will be, respectively, \$7,200,300, \$6,000,000, and \$2,710,000, making a total of \$15,910,300.

PITT RIVER POWER CO.

43. An entirely new project, which was carefully investigated, is now known as the Pitt River Power Co., and is intended to develop power at two locations on the lower Pitt River by the construction of two dams, each giving a first possible development of about 32,000 kilowatts. Favorable recommendation was given to this project, as its development could be secured at a reasonably early date.

44. This power project at 60 per cent load factor will give, with 32,000 kilowatts installed at the lower dam site, an output of approximately 168,000,000 kilowatt hours per annum, and with the two installations will give approximately twice this amount. This power will either have to be delivered to the general network through contractual relationships or delivered by its own transmission line to the industrial centers as far as San Francisco.

45. The cost of each one of these developments will be approximately \$3,000,000 or \$6,000,000 total without transmission lines, and they will take approximately two and one-half years to build. Surveys are being made on these projects, and they appear at this moment to be the only hydro developments on which any progress is being made.

SOUTHERN DEVELOPMENTS.

46. There are developments contemplated by the Southern California Edison Co. and the Southern Sierras Power Co., as well as by the San Joaquin Light & Power Corporation. The city of Los Angeles contemplated the development of approximately 21,000 kilowatts in connection with their aqueduct at Plant No. 2. Without considering the latter project, the total additions to the systems approximate a cost of \$48,000,000, and, so far as the investigations go, it is probable that all of this power can be easily absorbed within two years after development.

Program of Southern California Edison Co. developments.

	Approximate estimated costs.	Kilowatt hour to be installed.	Kilowatt hour output.	Time to construct.
Installation of additional unit at Big Creek No. 2 (short pipe line from end of 42-inch section to power house)	\$1,050,000	16,000	20,000,000	18 months.
Diversion of Pitman Creek into Huntington Lake, increasing water supply for existing plants	800,000	.....	30,000,000	15 months.
Contingencies on items 1 and 2	150,000	.....	.....	.....
Completion of Kern River No. 3:				
Power plant	5,000,000	.....	.....	.....
Transmission line	1,000,000	.....	.....	.....
Substation at Magunden	500,000	.....	.....	.....
	6,500,000	30,000	180,000,000	18 months.
Development of Shaver Lake for use in Big Creek No. 2:				
Shaver Lake	2,500,000	.....	.....	.....
Additional unit in Big Creek No. 2	1,500,000	.....	.....	.....
	4,000,000	16,000	75,000,000	2 years.
Development of Big Creek No. 3 to use Huntington Lake, Pitman and Shaver Lake water	7,500,000	51,000	206,000,000	2 years.
Total	20,000,000	113,000	505,000,000	

SOUTHERN SIERRAS POWER COMPANY DEVELOPMENTS.

47. This company has a program of development, which has been carefully compiled, intended to meet the growing load on its extended system. The conditions which have obtained and now exist are set forth in the following table:

*The Southern Sierras Power Co.***PLANT FACILITIES.**

	A.	B.	C.	D.
	Kilo volt-amperes, normal rating.	Maximum capacity, 15 minute peak kilowatts.	High-water kilowatts.	Low-water kilowatts.
(1) Hydroelectric:				
Bishop Creek No. 2	6,000	5,800	5,600	.....
Bishop Creek No. 3	6,750	6,900	6,900	.....
Bishop Creek No. 5, Tujo Co.	1,500	1,650	1,650	14,000
Bishop Creek No. 6	2,000	1,750	1,750	.....
Bishop Creek No. 4	6,000	6,000	6,000	.....
Mill Creek Mono Co.	3,000	3,000	3,000	400
Silver Lake Ruck Creek	10,000	10,000	10,000	10,000
Total hydro	35,250	35,100	35,100	24,400
(2) Steam plants:				
San Bernardino	11,250	8,000	.....	.....
El Central (steam)	250	250	.....	.....
El Central (gas)	750	650	.....	.....
Total steam and gas	12,250	8,900	.....	.....

Total:	Kilo volt-amperes
A-1 and A-2	47,500
B-1 and B-2	44,000
D-1 and B-2	33,300

MAXIMUM DEMAND.

Date.	Amount in kilowatts.	Favorable capacity, 44,000 kilowatts (excess).	Unfavorable capacity, 33,300 kilowatts (excess).
Sept. 23, 1913.....	15,740		
Aug. 17, 1914.....	20,250		
Oct. 7, 1915.....	22,120		
Sept. 22, 1916.....	22,600		
July 17, 1917.....	28,600	15,400	4,700
June 15, 1918, to Sept. 1, 1918, only.....	28,600	15,400	4,700
1919.....	34,500	9,500	11,200
1920.....	39,500	4,500	16,200

¹ Deficiency.

Average connected kilowatt per kilowatt of demand, 1.43.

SAN JOAQUIN LIGHT & POWER CORPORATION DEVELOPMENTS.

48. This company is working with a very small reserve as shown in the following Table VI, and has worked out a building program covering the next four years which should materially assist in assuring them greater protection and at the same time care for the heavy increase in the loads which are clearly anticipated.

TABLE VI.—*San Joaquin Light & Power Corporation.*

PLANT CAPACITIES.

	A	B	C	D
	Normal rating kilowatt.	High-water maximum capacity 4-hour peak.	Average capacity month of normal year.	Peak capacity month of extreme low year.
(1) Hydroelectric:				
Crane Valley.....	1,000	1,000	965	
San Joaquin No. 3.....	2,000	2,400	2,400	
San Joaquin No. 2.....	3,000	2,260	2,115	
San Joaquin No. 1-A.....	425	425	395	
San Joaquin No. 1.....	16,000	18,000	13,270	
Tule River.....	6,000	4,500	1,200	
Kern River.....	3,750	3,300	3,200	
Merced River.....	500	500	50	
Kittredge.....	875	875	50	
Total hydro.....	33,050	32,750	23,665	29,000
(2) Steam plants:				
Bakersfield.....	11,250	¹ 11,250		
Betteravia.....	2,000	¹ 2,000		
Fresno.....	750	¹ 750		
Total steam.....	14,000	¹ 14,000	14,000	14,000
Total hydro and steam.....	47,050	46,750	37,665	43,000

¹ Overload capacity.

MAXIMUM DEMAND—CAPACITIES AND SURPLUS.

Date.	Amount in kilowatts.	Condition B 46,750 kilowatts.	Condition C 37,665 kilowatts.	Condition D 43,000 kilowatts.
September, 1918.....	34,000	12,750	3,665	9,000
September, 1919.....	42,000	4,750	¹ 4,335	1,000
September, 1920.....	50,000	¹ 3,250	¹ 12,335	¹ 7,000

¹ Deficiency.

49. This company's lines are connected to the system of the Southern California Edison Co. at a number of points.

CALIFORNIA-OREGON POWER CO.

50. The California-Oregon Power Co., in the northern part of the State, has no shortage, but has a disproportionate excess of power. Arrangements have been consummated for the electrical connection of its system to that of the Northern California Power Co., so that 8,600 kilowatts can be delivered to the latter company and the same amount, by displacement, can be delivered by the Northern California Power Co. to the system of the Pacific Gas & Electric Co. at Colusa Corners. This was discussed and arranged for nearly a year ago (winter of 1918), when shortage of power was anticipated by the Pacific Gas & Electric Co. About January 8, 1919, this series of connections was completed to the extent that 4,500 kilowatts could be delivered to the Pacific Gas & Electric Co. The California-Oregon Co. can develop 12,500 kilowatts at a No. 2 station on the Klamath River, a short distance below their present Copco plant, by an expenditure of about \$1,541,000, but have no market for this power unless further amounts can be sent southward to the system of the Pacific Gas & Electric Co. over the Northern California Power Co.'s system. The item is included in the following Table VII:

TABLE VII.—Present and proposed capacities of power companies in California.

Name and location. of company.	Present hydro.		Present steam.			Proposed hydro kilowatts.	Proposed steam kilowatts.		Cost of new development.	Time of completion.
	Maximum.	Mini- mum.	Maximum.		Mini- mum.		Horse- power.	Kilowatt.		
			Installed.	Usable.						
Pacific Gas & Electric Co., San Francisco	{ R. 121,600 H. 122,600 }	{ 90,000 Low water. }	{ A. 49,000 B. 5,000 C. 21,000 SF20,000 O. 10,500 NB27,000 Bollers only. 10,402 HP }	{ 45,000 6,500 17,000 15,000 10,500 18,000 only. }	{ 40,000 6,500 13,500 15,000 10,500 18,000 only. }	125,000	A. 5,138 C. 2,469 None. None. NB2,500	15,000 6,000 None. 9,000	\$527,000 \$7,200,300 6,000,000 2,710,000	{ No. 2 Station 24 years For- dyce Spaulding, Bowman, 1 to 1½ years. 2 years. 1 year; 3 years for Big Dam.
Pitt River Sheep Rocks.	{ R. 25,365 H. 19,310 }	{ 16,200 Low water. }				32,000 12,500			3,000,000 1,541,000	2½ years. 1½ to 3 years.
California-Oregon Power Co., San Francisco									\$20,978,300	
Total cost, Northern.										
Southern California, Edison, Los Angeles	116,000	87,000	106,000		77,000	113,000			20,000,000	1½ to 2 years.
Southern Sierra Power Co., Riverside	35,100		8,900		48,600	5,138,000			5,138,000	1 to 3 years, 1918 to 1921.
San Joaquin Light & Power Corporation	{ R. 33,050 H. 32,750 }	23,665	14,000	14,000	14,000	(14)	(15)	(16)	\$48,089,000	1 to 4 years.
Total cost, Southern.									\$69,067,300	
Grand total										

1 Bear River.

2 Bollers.

3 Hydro.

4 Feather River.

5 Stanislaus River.

6 Generated.

7 Steam.

8 North Beach Station.

9 Pitt River.

10 Without transmission line.

11 Proposed dam, etc., No. 2 Station Klamath River.

12 Co. line tower.

13 49,500; first 204,500 ultimate including above.

14 \$7,700,000, including lines and substations, \$22,950,000 ultimate.

INTERCONNECTIONS.

51. At the present time there exist many interconnections between the companies in and about the bay district so that they can exchange power between their systems. These are shown in the following list:

Existing interconnections.

- I. In the bay region:
1. Pacific Gas & Electric Co. and Great Western Power Co. at Oakland¹----- 5,000 kw. at 11,000 v.
12,000 kw. at 60,000 v.
 2. Pacific Gas & Electric Co. and Sierra & San Francisco Power Co. in San Francisco—
 - a. Bay Shore—Martin----- 10,000 kw. at 11,000 v.
 - b. North Beach—Station F----- 15,000 kw. at 11,000 v.
 - c. Martin—Bryant Street taken out... 4,000 kw. at 11,000 v.
 - d. Martin—Geneva now in Nov. 29, 1918----- 4,000 kw. at 11,000 v.
 3. Great Western Power Co. and Sierra & San Francisco Power Co.—

Tie line connecting steam plants----- 9,000 kw. at 11,000 v.

The last connection is temporarily out of service, due to the absence of switching equipment at the Sierra end. Not now in Nov. 29, 1918.
- II. In other parts of northern and central California:
1. Pacific Gas & Electric Co. and Snow Mountain Water & Power Co. at Santa Rosa¹... 6,000 kw. at 60,000 v.
Nov. 29, 1918, Great Western Power Co. and Snow Mountain Co. at Santa Rosa ----- kw. at -----
 2. Pacific Gas & Electric Co. and Western States Gas & Electric Co. at Folsom----- 3,000 kw. at 60,000 v.
 3. Great Western Power Co. and Western States Gas & Electric Co. at Folsom----- 1,000 kw. at 22,000 v.
 4. Sierra & San Francisco Power Co. and Western States Gas & Electric Co. at Manteca... 2,000 kw. at 80,000 v.
 5. Pacific Gas & Electric Co. and Western States Gas & Electric Co. at Stockton^{1, 2}... 2,000 kw. at 2,200 v.
 6. Pacific Gas & Electric Co. and Northern California Power Co. at Chico¹----- 10,000 kw. at 60,000 v.
 7. Northern California Power Co. and Western States Gas & Electric Co. at Junction City¹ 3,000 kw. at 60,000 v.
 8. Pacific Gas & Electric Co. and Coast Counties Gas & Electric Co.—

At Davenport----- 2,250 kw. at 24,000 v.

At Morgan Hill----- 3,000 kw. at 24,000 v.
 9. Sierra & San Francisco Power Co. and Utica Gold Mining Co. at Angeles Camp¹----- 1,000 kw. at 17,000 v.
 10. There is, at the present time, under construction between the Sierra & San Francisco Power Co. and the Coast Counties Gas & Electric Co. at San Juan¹----- 3,000 kw. at 24,000 v.

NEW INTERCONNECTIONS RECOMMENDED.

52. An additional interconnection is recommended between the Sierra & San Francisco Power Co. and the Pacific Gas & Electric Co. near Mission San Jose.

53. This would call for the Pacific Gas & Electric Co. temporarily to terminate its Wise line at Mission San Jose, and step-down at

¹ These interconnections are in daily service.

² Will be increased.

that point from 100 to 50 kilo volts. This should be completed at as early a date as possible. Then by the construction of a branch 100-kilo-volt line from Mission San Jose to connect with the main line of the Sierra & San Francisco Power Co., distant approximately 1 mile, a connection will result between the two systems of sufficient capacity to meet all present requirements.

54. It is also extremely desirable for the companies to arrange for so complete interconnection of the steam stations, both in San Francisco and Oakland, that there would be need for only one steam station of sufficient capacity to take care of the breakdown service, regulation, and the short-time peaks on the three interconnected systems. With the present high price of oil and labor the writer believes that economies can be secured which would be extremely desirable.

REGULATIONS OF DEPARTMENTS OF AGRICULTURE AND INTERIOR.

55. The writer has made a careful study of the regulations and rules and laws of the Departments of Agriculture and Interior in so far as they relate to hydroelectric development and control. The opinions in regard to the effect of the present rules and regulations and stipulations differ so widely that it is almost impossible to determine what changes in the present laws, or what recommendations as to alterations in pending legislation, will make for the more rapid development of hydroelectric power. Certainly the main ideas that are undesirable are the revocable permit, the definite franchise stipulation, the matter of just compensation, and the power to be exercised over the complete operations of the company as to conduct and rates. These appear to be the crucial points in all the present and proposed legislation in regard to the power companies. If these can be corrected, the writer believes that the financing of the companies and the development of water power can be much more readily secured.

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MAY 3 1922



